DROWNING DETECTION SYSTEMS:
RESEARCH PROJECT

CONTENTS

ACKNOWLEDGEMENTS

Thank you to the staff at all facilities that took part in testing, pre-testing and focus groups.

Thanks also to all members of the stakeholder group who offered their time, knowledge and expertise to assist with the project implementation.

INTRODUCTION

There is currently little independent research on the effectiveness of Drowning Detection Systems (DDS). The terms DDS covers electronic systems that can assist with pool and swimmer surveillance. There are published standards that DDS must conform to, but the lack of evidence on their suitability and effectiveness alongside the high cost of installation are currently barriers to installation in public and private pools. DDS are not designed to totally replace lifeguards, but to assist them in identifying and locating swimmers who are potentially drowning. The technology used in DDS has advanced in recent years, driven by the improvement in the Artificial Intelligence that is used in many types of system.

This research project has been funded by Sport England and carried out by the ukactive Research Institute over the course of 2019. It consisted of extensive information consolidation, independent testing of DDS systems and exploration of attitudes towards lifeguarding and DDS. The project was undertaken with the knowledge of the manufacturers of the four systems that were tested, and the understanding that results from specific systems would not be individually published. This research piece was undertaken to establish the overall performance of a selection of DDS in test conditions, not to evaluate or compare systems against each other. For this reason, all test results are included at an aggregated level only. For this project, all pools that were tested were 25 metre tiled pools.

Project Governance

Throughout the course of the research, the ukactive project team reported back to an advisory group consisting of key stakeholders from across the sector. This group met in person three times throughout the course of the project to discuss progress, share updates and also to share specific knowledge that could aid the project. The group also helped with the development of some of the work strands including the creation of live and enhanced testing standards. By sharing updates with this group we were also able to ensure the process was completely transparent and all relevant parties were being kept informed.

We would like to thank all the members of this group for giving their time and expertise and fully engaging in the project.

Stakeholder Group
Operator representatives (GLL, Places Leisure, Everyone Active, Bourne Leisure)
Manufacturers (AngelEye, Poseidon, Poolview, SwimEye)
SPSC Pool Safety Specialists
Sport England
Swim England
ROSPA(Royal Society for the Prevention of Accidents)
RLSS (Royal Life Saving Society UK)

PROJECT OUTLINE

Eight areas of work were initially identified. These are outlined below, with outcomes and results from each area following in the report. As the project progressed, it became apparent that it would not be possible to complete area six '**Analysis of current DDS test documentation with reference to published standards'**, as there was limited instances of recorded test results that were available to analyse. Following discussion with the stakeholder group, it was also apparent that more emphasis on gathering insight from lifeguards would be useful, with the consequence that we undertook a lifeguard surveying exercise in addition to the work areas identified below.

1) Review of current literature about DDS and lifeguarding

The first part of the project will be to undertake a thorough and extensive review of the literature that is currently available around two key topics:

- The use of DDS in swimming pools
- The use of lifeguards and DDS in swimming pools and the procedures and protocols used

This will bring together all the current evidence on what DDS is, how it can be used and the impact it has had so far. This piece of work will also bring together the current standards and guidance on the installation, use and operation of DDS.

2) Summary of current DDS available

This will build on the work carried out in part 1 and will comprise a desk based review of the different types of DDS currently available on the market and how each of them work. We will identify the similarities and differences in functionality of each system.

3) Testing of current DDS against published standards

All DDS must undergo testing according to a specific protocol published in ISO_20380. We will organise and facilitate independent tests of the different DDS systems according to the current test protocol as described in ISO_20380. Each DDS system will be tested according to the key requirements in this standard. This is to ensure that all systems have been tested independently and the results of this can be documented. For this we hope to test all manufacturers which have DDS installed in the UK (as mentioned above). After the initial scoping exercise, this was extended to cover the four main manufacturers, one of which does not currently have an installation in the UK.

4) Testing of current DDS against enhanced standards

The current standard specifies that: "The dummy shall measure between 65 cm to 100 cm (length) × 25 cm to 50 cm (width) × 18 cm to 25 cm (depth), and weigh between 4 kg and 10 kg out of the water. The dummy should be wearing a woman's (one-piece) swimsuit, in a dark colour (to compensate for the lack of contrast from the dummy's texture)".

In order to demonstrate the reliability of DDS, we will facilitate an enhanced testing procedure for each DDS system, using a more stringent test protocol than the published standards. For this we will seek expert advice on how best to do this from the stakeholder group.

We anticipate that the DDS would be tested using the same test outline as ISO_20380, but with these more stringent conditions in place. This is to establish if DDS actually perform above and beyond the minimum standards.

5) Testing in 'live' conditions against both standards

The test scenarios outlined above take place in an empty pool. We propose a repeat of these tests, but undertaken in normal operating conditions e.g. with regular swimmers using the pool. We anticipate developing a live test protocol that enables tests to be carried out in the same way against both the standard and enhanced protocol. By testing under live conditions this should be a better replication of the conditions that DDS need to be reliable in.

6) Analysis of current DDS test documentation with reference to published standards
As part of the standard operating procedure, partial testing of the DDS system is required on a daily basis, with full tests having to be carried out every six months. The results from these tests must be stored. This part of the project would involve working with facilities to collate and analyse the test results from the various DDS and analysing how the systems have performed against the test standards over time.

From this we would look to identify overall rates of adherence to the standards over time, and pinpoint any recurring trends in test failures.

7) Operator focus groups/ engagement
We would run focus groups with major operators (or have individual meetings if appropriate), including those who have pools with DDS and those that don't, to establish what the current views towards using the systems are.

This would include topics such as:

>> Why they do/ do not have DDS in their pools
>> Barriers to installing DDS
>> Opinions on the use of DDS
>> Thoughts on lifeguarding protocols at their pools

This would give us valuable feedback including real life examples and experiences of operators who use DDS. It would also identify areas which may need additional work to overcome any barriers to using DDS.

8) Lifeguard focus groups
The final part of the project will involve running focus groups with lifeguards. Those who take on this role stand at the front line of defence against drowning and we anticipate them having a wealth of knowledge that we will be able to access to contextualise the use of DDS.

We will speak to a range of lifeguards- those who use a DDS as part of their role, those who do not, and those who have experience both with and without a DDS. The key themes we will explore include:

>> Experiences (positive and negative) of lifeguarding
>> Experiences (positive and negative) of lifeguarding using DDS
>> The most difficult parts of lifeguarding
>> Concentration levels whilst lifeguarding
>> Reaction speed to incidents whilst lifeguarding
>> Do lifeguards feel adequately prepared to undertake their role?

These focus groups will be semi structured to allow conversation to flow naturally and to cover any topics the group feel are relevant. They will be run by an experienced researcher to ensure that conversation is balanced, and questioning does not endorse one style or method of lifeguarding over another. These sessions will not actively endorse DDS but will instead seek to gather honest feedback around the role of lifeguards. Typically they would last for one hour and will take place at the lifeguards' place of work.

1. LITERATURE REVIEW

1. Introduction

Recently, there has been growing interest around the topic of drowning detection systems (DDS) in the sport and leisure industry both across the UK and globally. Advancements in technology, coupled with the importance of pool safety, has led to its growing prominence, with mention of DDS now in documents such as HSG179 – the latest UK standards document for health and safety in swimming pools (Health and Safety Executive, 2018). However, the topic is a debated area for various reasons explored in this review.

Whilst there are plenty of academic articles dedicated to the technology and design behind these products in the fields of biometrics, computer science and electronic engineering, there is limited academic research investigating their application to real-world scenarios. Furthermore, there is uncertainty around their use alongside traditional lifeguarding; whether international testing standards (ISO standards) are robust enough; and general risks affecting the effectiveness of these products. This includes factors such as water clarity, high pool occupancy, lighting, glare and attractions such as water slides and wave machines. These concerns alongside the lack of research and high installation costs have resulted in a reluctance by some operators to incorporate DDS into their pools. This signifies the importance of independent research into DDS. Along with the specific aims outlined in chapter 2, this literature review intends to support the move towards the shared goal of improved pool safety.

This piece will begin with an overview of the different definitions of DDS, followed by an explanation of the aims and methodology of this review. It will then discuss what the current DDS standards are alongside legislation and guidance available around DDS, and provide a summary of the shared responsibilities towards the effective operation of DDS. Following this, the literature review will examine the co-existence between DDS and traditional lifeguarding, provide an analysis of its impact so far, and conclude with recommendations on the direction of future DDS research.

2. Definitions

Of the differing definitions of DDS, most outline three defining elements: 1) surveillance, 2) detection of a pool user in difficulty, and 3) raising an alarm (Health and Safety Executive 2018, ISO 2017). For example, ISO_20380 (the document published by the International Organisation for Standardization (2017) outlining the international safety requirements and test standards for DDS) defines the technology as an ‘automated system including means for digitizing series of images of people in the pool basin, means for comparing and analysing digitized images and decision means for setting off and sending an alarm to trained staff when a detection occurs’. In comparison, there are broader definitions that are inclusive of other technologies that focus on the surveillance aspect, for example, 'DDS is used to describe various electronic systems that are designed to assist with the surveillance of swimmers within the water of a swimming pool' (Sport England, 2011). This definition would include CCTV that helps give lifeguards an underwater view but does not have the capacity to detect a pool user in difficulty or raise an alarm. For this to be effective, staff would have to make sure the CCTV is being monitored at all times, making the staff experience with this very different to the experience of using a DDS falling under the first definition. It is important to distinguish what exactly constitutes a DDS as there are different areas of responsibility required from different actors involved in the effective operation of DDS, which will be examined in chapter 4. For this literature review, research has focused on the definition used by the ISO and other sources that incorporate all three elements of surveillance, detection and alarm raising.

3. Aims and Methodology

3.1 Aims

This literature review aims to:

- Establish and outline what is known on Drowning Detection Systems.
- Evaluate the current literature on Drowning Detection Systems, including their use in indoor pool environments along with interaction with traditional lifeguarding.
- Better understand where DDS are positioned in the health and safety landscape of indoor swimming pools.

The value that can be generated from these aims stem from the recognition that currently, there are no published documents drawing together all the current DDS research. The literature review aims to contribute as independent research in this field and hopes to signpost the potential future direction of DDS research.

3.2 Methodology

The methodology of this review began with establishing a search plan. This involved generating a list of key search terms. As DDS are a global concept, it was important to consider the various synonyms and acronyms under which they are known. The sources identified were then shortlisted according to relevance and reviewed, keeping in mind the potential for bias in market based literature, or literature drawing from funded research that may compromise its partiality. The literature review draws from a range of sources including standards documents from international and national bodies, reports, academic articles, books, online articles, and news reports. To supplement this, a group of key stakeholders involved in pool safety were consulted to signpost towards any sources that were felt to be relevant to this review. Sources on DDS in outdoor environments are beyond the scope of this literature review and have been excluded due to the challenging variance compared with indoor swimming environments.

4. Standards, Guidance and Responsibilities around DDS

4.1 Safety requirements and guidance for DDS and testing standards

This section will draw from three core documents: ISO_20380, HSG179, and the recently published German guideline, DGfdB R 94.15. A summary of each is given, outlining the key messages they disseminate and what this means for those involved with DDS.

ISO_20380

This document focuses on the requirements for the installation, operation, maintenance and performance of DDS, the testing methods, and the information required from the supplier in the operating manual. These international standards do not apply to systems used in domestic pools or pools smaller than 150m^2.

Prior to the installation of any DDS, 'a technical study shall be carried out by the supplier in consultation with or based on information provided by the swimming pool's owner/operator'. This is to establish the quantity and positioning of the equipment making up the system such as cameras, central processing unit, alarm tools, and other related equipment. The technical study must also provide a technical drawing of the pool basin, showing areas of 'coverage' and 'non-coverage', as well as the minimum lighting levels required above and below the water surface for the DDS to operate within performance requirements. To carry out the study, a list of factors to consider are given, outlining the variables that make each pool unique such as the architecture, and alarm reception coverage area of mobile devices to be used with the system. With this information all in one document, the technical study can be used to help optimise performance of the system, and forms part of the contract between the supplier and the pool operator.

The next area of the standard is the performance requirements. This outlines the requirements needed to pass the regular maintenance testing and performance requirements for normal operation. This section covers the alarm set off time for operational performance, which is to be 15 seconds or less and displayed on the system interface. It also states that the alarm set off time must be built-in and shall not be changeable by staff. The section also discusses the areas covered by the DDS and highlights that each trained staff member must be aware of these areas. Another coverage-related requirement is that the DDS must be able to temporarily create areas where detection is disabled, to manage specific activities such as rescue drills. These disabled areas must be freely determinable by trained staff and the duration of non-detection within these zones. Along with specifying that staff must be able to change non-detection settings at any time, a high level of detail on the automatic-reactivation of temporary non-detection zones and how they display on the system interface, is provided. This is important as it suggests the active role trained staff must take in operating DDS to suit the individual operating needs of their pool.

Further requirements outlined are for the detection performance and false alarm rates. This states that the detection rate must be 80% or higher, and that one alarm for every detection must be activated. Requirements for the hardware specify that the DDS must 'show in at least two different ways' that the hardware is in operation. It also specifies that the system must not only inform staff immediately when detection performance is deteriorating but also the nature and level of deterioration. The DDS must be able to set off alarms 'without any manual calibration between detections' and it must have the capacity to detect multiple incidents occurring at the same time in different places. Although detecting multiple incidents simultaneously is a performance requirement, it is not part of the regular testing protocol outlined later in the document. The final performance requirement is that 'there shall not be, on average, more than five false alarms per day... during public opening hours over a 30 day period'.

Following this, ISO_20380 outlines the way data from the DDS is communicated and managed. For example, operators must keep a data and alarm log 'covering the last 30 days during public opening hours'. Whilst this is an explicit requirement, there is no system to ensure operators have complied. The sections on 'Alarm data' and 'Operational data' stipulates the requirements for the alarm sound, what information should be displayed, how alarm data is stored when the alarm is triggered, and the methods by which the alarm is received. This is so data can be analysed or referenced when needed, encouraging insight into performance of the system.

The section outlining the test splits into two parts. The first is the non-detection test that the DDS must pass before the second test, detection, can be undertaken. The purpose of the testing is to 'verify the basic functions of the system' and to 'prove that the monitored area, defined in the technical study, is covered'. There is also a recommendation that an additional test under real operating conditions is included, however, this is optional. Operators must record data from the operational test and ensure this is passed onto the DDS manufacturer for the 'development and continual improvement of the system'. Again, there are no checks to ensure this requirement is adhered to.

For both the non-detection and detection test, ISO_20380 sets out the test preparation and conditions needed for the tests and their procedures. For the non-detection test, the DDS must not detect the swimmer any more than twice out of five times in order to pass.

In comparison to the optional operational test, the regular detection test must be carried out 'in strict accordance' with certain conditions. These include that there should be no swimmers in the area covered by the DDS, the water clarity should be compliant with legislation, the lighting to be artificial and at least equivalent to that requested by the supplier in the technical study and that the DDS central processing unit shall not be connected to any external network while the detection test is being carried out. If a pool has a moveable floor, the operator must carry out the test twice at different depths.

Within the detection test preparation, an important consideration is the test manikin/ dummy that is used. The standard states that 'the dummy shall measure between 65cm and 100cm (length) x 25cm and 50cm (width) x 18cm and 25cm (depth), and weigh between 4kg and 10 kg'. The dummy should be wearing a woman's (one-piece) swimsuit, in a dark colour'. The section then gives details of the rope requirements, how the pool basin is to be divided for the testing areas, and how the results should be recorded, measured and reported. In summary, the dummy, attached to a rope, must lay motionless at the bottom of the pool basin in each of the testing areas. Staff must then record whether the alarm triggers within 2 seconds of the set-off time (e.g. within 13 and 17 seconds if the set-off time is set at 15 seconds). This is recorded as a detection.

The full test described above, must be carried out every 6 months. In addition, a daily test must be carried out before public opening hours. This consists of immersing the dummy at a random position before public opening hours and observing the results. For both the daily testing and the full test, trained staff must note the results and 'take appropriate actions' if the system fails either test. However, the standard does not give detail on what those appropriate actions could be. For the test reporting, ISO_20380 provides a list giving the minimum data requirements for the report. This includes details of the trained staff involved in testing, the particular pool, the DDS supplier used and type as well as the conditions during testing such as lighting conditions, water clarity, date and time.

HSG179

HSG179 (fourth edition) is the latest UK standards document on pool safety by the Health and Safety Executive (2018). Aimed at pool operators, it offers guidance on how to comply with the law in the management of health and safety for public swimming pools. The standards compliment the requirements outlined in BSEN 15288-1 and 2, which are the European standards. Unless specifically stated, the guidance is not compulsory which means that operators are free to take other action as a means to comply with the law. This edition of the standards document is the first to have a section specifically dedicated to drowning detection systems. Although other areas of the document do not directly refer to standards of DDS, they specify standards that impact the performance of DDS and operators must understand how their DDS interact with UK pool standards.

The document states the key pieces of legislation pool operators must be aware of. This means that operators using a DDS must always keep this in mind to consider how their DDS works within these. The main pieces of legislation to consider are the Health and Safety at Work Act, the Management of Health and Safety at Work Regulations, and Reporting of Injuries, Diseases and Dangerous Occurrences Regulations. In addition, there exists the Corporate Manslaughter and Corporate Homicide Act, which may be relevant to drowning incidents if there are serious management failures resulting in a gross breach of a duty of care.

One of the main features for managing health and safety around pools is the pool safe operating procedures (PSOP). This consists of the normal operating plan (NOP) and the emergency action plan (EAP). Operators using DDS must be sure to incorporate DDS into their PSOP as it must set out how the pool operates on a daily basis. This includes details of the equipment used and manner of use by trained staff.

Control of admissions is an important part of health and safety in pools. This should be a prime consideration for those operating pools with DDS as high pool occupancy can affect the performance of DDS (Sport England, 2011; Haizhou Li et al., 2012). The Health and Safety Executive guidance states that operators should implement effective ways of controlling and recording the numbers of people entering the pool, giving suggestions of how to do so. It also offers guidance from BS EN 15288 that a typical starting point for determining an occupancy ratio is $3m^2$ of water per pool user. Whilst this is an important consideration, the occupancy ratio is a guide rather than a legal requirement. Similarly, with child admissions, health and safety law does not prescribe what the adult: child ratio should be for young children under the age of 8 under the supervision of a responsible person aged 16 or over, however, it is reiterated that this should be an important consideration for operators. This is an important consideration – according to the American Academy of Pediatrics (2019), drowning in pools is a danger especially for younger children.

When establishing the level of supervision required for a pool, it is stated that operators 'must have robust systems to ensure the safety of pool users' which should focus on factors such as 'identifying pool users in difficulty' and 'preventing pool users from getting into difficulty by intervening early'. Both of these factors align with the aims of DDS and so operators should ensure their DDS are well maintained and working at optimum performance to fulfil these requirements, following the correct maintenance and test protocol.

As a legal requirement, a risk assessment must be carried out as part of the process for determining the level of supervision required in the pool. Of the list of risk assessment considerations outlined in HSG179, glare, reflections, blind spots and occupancy levels are highlighted which are all issues that can affect the performance of DDS. This shows that operators should already be upholding the UK pool standards by paying close attention to the list of considerations in the risk assessment, which affects how operators with DDS can mitigate the risks for their DDS performance. The guidance specified for lighting is that it must be 'suitable and sufficient', and that the glazing must be maintained to uphold the standard of lighting, minimising the amount of reflection and glare. Lighting that impairs the visibility of the pool floor is considered unsafe in the standards. To ensure there is no lighting deterioration, it advises to check illumination values annually.

HSG179 also encourages the use of technology and DDS as a precaution 'where constant poolside supervision is not provided', which could include pools located in gyms or hotels. Following this, the subsection on 'Using technology to aid observation' acknowledges that although such technologies have their limitations, they have assisted lifeguards in identifying 'potential drowning accidents they had not observed'. It offers further guidance and warning such as warnings for operators not to assume that the system can detect all possible drowning incidents unless the manufacturer is able to guarantee it.

Primarily, the guidance places importance on establishing procedures to ensure that all alarms generated by the DDS are responded to promptly and as a legal requirement, staff must be trained in their use, taking into account both the PSOP and the manufacturer's instructions. The guidance places responsibility on the operator to ensure the DDS equipment is tested and maintained in accordance with the manufacturer's instruction, as well as giving reference to ISO_20380 for more information.

Further areas of the document are standards surrounding poolside equipment and features. Whilst these do not directly relate to DDS standards, operators should keep them in mind as they can impact the installation and performance of DDS. Operators need to consider poolside features when deciding the compatibility of a particular DDS. For example, underwater cameras that protrude from the pool walls may not be compatible with moving floors. Features such as slides and play structures could potentially obstruct the camera view. Where inflatable play structures are used, HSG179 advises that underwater lights and cameras could help with observation underneath the equipment.

DGfdB R 94.15

The most recently published document out of the three core standards documents reviewed is the German guideline for 'Test methods for camera-based drowning detection systems under operational conditions' (DGfdB R 94.15), released in June 2019. Created through a partnership between the German Institute for Standardisation and the German Association for Public Swimming pools, the guideline refers to ISO_20380 throughout. It is self-described as a guideline to 'supplement' ISO_20380. The document follows a closely similar structure to its international counterpart. The main difference is the increased focus on the optional testing in live conditions, emphasising in the foreword that 'the test situation shall be as close as possible to the real conditions of usage, especially in regard of the pool occupancy and light conditions'. Further, it encourages repeat testing under varying conditions.

Another notable difference between the international standard and German guideline is the detection time, which is longer than the time frame outlined in ISO_20380. This is justified by the difference in testing conditions as it is stated that 'factors may arise that place higher demands on the detection software and may require a longer computing time'. The standard claims that whilst a shorter time does allow for a quicker rescue, it does not have a detrimental effect on the prognosis for victims of drowning accidents. Furthermore, the shorter the detection time, the potential higher rate of false alarms.

Although there is an emphasis on carrying out the testing in live conditions, there is no guidance on a minimum number of swimmers to create test conditions. Operators are encouraged to ensure a 'suitable number of users' are used in the pool during testing. This is due the individuality of each pool. In section 6.2, under the person requirements for carrying out the testing it simply states that 'The tests as per 6.5 and 6.6 shall be carried out by a competent person' without reference to experience or training. In contrast, where DGfdB R 94.14 is enhanced in comparison to ISO_20380, is the test specimen used for testing. As DGfdB R 94.15 centres towards replicating operational conditions, there is a choice in the test specimen used. This can be either an adult male, adult female or a rescue dummy. ISO_20380 differs in not only the lack of choice for test specimen but also the type of dummy used for testing. In Annex A of DGfdB R 94.15, there is an image of an example specimen dummy, alongside the dummy requirements, which are that it must have moveable limbs, have negative buoyancy and be between 0.9m and 1.2m in size. Essentially, the dummy requirements for DGfdB R 94.15 are more human like and encourage operators to undertake multiple tests using different test specimens with different types and shades of swimming costume. Specifically, it states that 'The test specimen's bathing costume shall display as little contrast against the wall or pool bottom as possible' whereas ISO_20380 is more restrictive, stating the dummy should be wearing 'a woman's (one-piece) swimsuit, in a dark colour'.

Like ISO_20380, the test procedure splits into non-detection and detection tests. In terms of evaluating the tests, DGfdB R 94.15 has more stringent pass requirements. For the non-detection test, no alarm must sound for the system to pass, using between 5 and 8 persons (depending on pool size). For the detection test, the system passes if it achieves a 90% detection rate or higher. The document also outlines how to record the results and the minimum requirements for the test report, which is largely similar to the reporting requirements of ISO_20380.

4.2 Division of responsibility

Across the literature, the division of responsibility between those involved in the effective use of DDS broadly splits into four groups. They are the DDS manufacturers, pool designers, pool operators and trained staff / lifeguards.

Pool designers

Across the literature, there is agreement that DDS are best incorporated at the design stage rather than retrospectively fitting the system, both for new and refurbishment projects (ISO_20380; Sport

England, 2011; British Standards Institution, 2018; DGfdB R 94.15, 2019). Designers should ensure that their pools are DDS friendly and that design features do not affect the performance of a system. Design features such as the shape of the pool are important, as the design should be mindful of avoiding potential blind spots in the pool. The same considerations are important for pool side features such as water slides, as well as the colour of materials which should not reduce the visibility of a body lying on the pool floor. These design considerations fall within the duty of the designer under the Construction, Design and Management Regulations (CDM) to 'eliminate hazards that may give rise to risks, and reduce risks from any remaining hazards' (Health and Safety Executive, 2018). Pool designs should be DDS friendly, minimising the inconvenience of installation for the operator and not affect the vision, hearing or concentration of trained staff (Health and Safety Executive, 2018).

Manufacturers & Suppliers

Manufacturers are responsible for ensuring their product works and adheres to the relevant standards such as ISO_20380. Before the installation of any DDS, manufacturers must ensure that their product is compatible for a particular pool. To do so, they must ensure the methods used to do so are robust enough to make a suitable decision. For operators and trained staff to use their products effectively, manufacturers are responsible for ensuring their instructions are clear. This is also true for the products limitations, which must be clearly communicated. Additionally, it is stated in ISO_20380 that 'tests shall be carried out by the supplier, within 3 months after the start of the commissioning phase' meaning that the system cannot go live before full successful tests from the ISO test procedure are completed. Suppliers are also responsible for carrying out the technical study outlined in ISO_20380. This requires the co-operation of the pool operator to provide the relevant information.

The supplier is responsible for providing a manual to the pool operators, with the following outlined in ISO_20380 as a minimum requirement: 'supplier reference number of the computer vision system installed; how to operate the system; a detailed description of the performances and limits of the system; a description of the performance measurement procedures to be carried out for regular testing; supplier contact details and contact details of the help line (opening hours, telephone number and e-mail address)'. Training must be provided by the supplier following installation of the DDS before it is used by the operator for the first time. Finally, responsibility lies with the supplier to offer regular maintenance services for the computer vision system's upkeep. At a minimum, maintenance services should include hardware maintenance for cameras and receivers, and software maintenance for monitoring, repairs, updates and upgrades.

Operators

Within the four sub-divisions involved with DDS, most of the responsibility lies with pool operators to ensure their DDS is performing optimally. As it is the operator's responsibility to carry out a risk assessment, they are responsible for using this process to identify any physical or procedural changes or management measures required to enable safe use of the pool.

If the installation of a DDS is a suitable change for the pool, or a DDS is already installed, operators are responsible for considering occupancy levels. This includes ensuring there are effective methods of controlling and recording admissions to the pool, as high occupancy levels and overcrowding can compromise the performance of DDS (Haizhou Li et al., 2012). The guidance offered by the Health and Safety Executive is $3m^2$ per pool user (2018). Similarly, operators are responsible for enforcing child to adult ratios that do not compromise the safety of pool users. Operators are also responsible for carrying out routine testing, adhering to the manufacturer's and ISO's instruction. Water clarity or turbidity is a vital factor in the performance of DDS. If water clarity is not sufficient, or decreases over time, it could obstruct the system from identifying a swimmer in difficulty. As public pools should have various alarm systems, it is important that the DDS alarm is distinctive from others such as a fire alarm. The Provision and Use of Work Equipment Regulations (PUWER) expands on the Health and Safety at Work Act and requires equipment supplied to staff to be 'suitable, used safely and properly maintained' (Health and Safety Executive, 2018). Glare is also an issue that operators are responsible for controlling. Glare can cause false alarms and impact the view of trained staff, negatively affecting DDS performance. This can be partially controlled through controlling lighting in pools.

Further DDS responsibilities for operators are around the trained pool staff. Operators should incorporate their DDS into the pool's PSOP, which should include details of equipment, the operating procedures for normal conditions, and the emergency action plan. It is the responsibility of operators to check staff understanding and competence in the PSOP, as well as enforcing effective methods for monitoring alarms with prompt procedures for assisting pool users in difficulty. Particular attention should be given to how staff are organised, trained and how lifeguards are deployed considering individual DDS set-ups. Operators should also be aware and act in accordance where staff may have other employment that may interfere with their lifeguarding duties. Operators should communicate with staff to ensure their shift allocation does not compromise their vigilance, for example if they are tired from completing a night shift in another job.

Trained Staff & Lifeguards
Whilst it is the operator's responsibility to oversee the training, organisation and competency of pool staff, the staff members themselves have individual responsibilities for working with DDS. This includes adhering to the PSOP, understanding its contents, what it is there for, and their role within it as individuals. Above all, trained staff and lifeguards are responsible for ensuring the safety of pool users, achieved through promoting responsible behaviour, identifying pool users in difficulty, preventing drowning incidents by intervening early and following the correct procedure to perform a rescue. To assist their lifeguard duties of identifying pool users in difficulty and intervening early, staff working with DDS should receive training in their use. Lifeguards must also take responsibility to ensure that any activities or employment outside of lifeguarding do not impact their ability to carry out their lifeguarding duties or operation of a DDS. Lifeguards are required to remain highly vigilant when working with DDS and not perceive the technology as a reason to reduce their concentration.

5. Co-existence with Lifeguards

Whilst literature on DDS mostly agrees on areas such as the risks and issues associated with DDS performance, there are other areas where sources offer differing points of view, for example, DDS and their co-existence with lifeguards. There is debate around whether DDS can be helpful or harmful towards lifeguarding practices and how DDS may change the landscape of traditional lifeguarding, as well as some disagreement on whether they serve as justification for reducing lifeguard numbers. The term 'blended lifeguarding' or 'modern lifeguarding' has been newly coined to describe the concept of traditional lifeguarding practices being blended with technology for drowning detection (Swimming Pool Scene, 2017). Currently, there is little qualitative or quantitative research analysing the experiences of lifeguards themselves relating to this concept. This section will review the literature from the core standards documents, DDS manufacturers, and lifeguarding studies to examine both the potential helpful or harmful effect they may have.

HSG179 (2018) and ISO_20380 (2017) both state that DDS can reduce staffing levels and observation by lifeguards so long as the risk assessment is able to demonstrate that the same level of risk control and safety can be maintained that would be provided by the human observation of a lifeguard. This aligns with sources that support the idea that DDS can reduce lifeguarding numbers and subsequently reduce staffing costs. DDS installation in the UK has faced similar criticisms, with one member of the public describing the system as a 'ploy to cut staffing costs' (Mirror, 2018). This raises questions as to whether DDS are threatening the stability of lifeguarding as part-time or full-time employment, as well as potentially damaging the appeal to train as a lifeguard.

The opposing side to this position is that increased use of DDS could attract more individuals to joining the lifeguarding workforce. Representatives of pool operators speaking at the physical activity conference Elevate in 2017, expressed belief that DDS 'has a significant role to play in the recruitment and retention of modern lifeguards'. This may be due to the extra level of reassurance and support DDS can provide for lifeguards who may be discouraged by the prospect and pressure of dealing with drowning incidents whilst maintaining other lifeguarding duties and responsibilities. DDS are viewed by some as an aid to lifeguards that can save vital seconds, preventing a missed incident from escalating into a tragedy (Wave, 2018), which can have lasting traumatic effects on a lifeguard's psychological and emotional health (Aquatics International, 2007).

Despite the claims that DDS can reduce staffing levels and human observation so long as a risk assessment demonstrates the same level of safety can be maintained, opposing sources disagree, claiming that this should not serve as a reason to reduce staffing levels. Although ISO_20380 mentions that the risk assessment can warrant the reduction of human monitoring, it also states that 'Computer vision systems are designed to complement lifeguards or trained staff and are not designed to reduce lifeguard supervision'. Similarly, chapter 13 of Advanced Topics in Biometrics (Haizhou Li et al., 2012) which examines swimmer behaviour analysis and early drowning detection at pools, states that the intention of DDS is to provide 'an additional level of safety on top of watchful eyes of lifeguards' rather than using DDS to reduce lifeguards and human observation. Furthermore, the German guideline describes the use of DDS as being 'only allowed as a support for poolside supervision'. Whilst there may be debate around whether this technology should or should not reduce some elements of lifeguarding, there is clear agreement that it should not wholly replace it. The reasoning being that DDS cannot communicate with swimmers, intervene to prevent inappropriate behaviour or perform a rescue (Health and Safety Executive, 2018), and therefore cannot exist as a threat to replacing qualified lifeguards altogether.

Supporting literature on how DDS can be helpful to lifeguards comes from studies on human vigilance limits that show how lifeguards often cannot maintain constant high-level surveillance at all times. In 'The Science of Beach Lifeguarding', Smith's (2016) chapter on recognition, vigilance and surveillance techniques quotes studies that suggest the optimal level of vigilance capacity cannot be maintained for more than 30 minutes, and factors such as stress, fatigue and monotony can affect performance. Lifeguards working or volunteering part-time often have other employment and commitments, and so could be at risk from tiredness. Whilst operators and lifeguards should take measures to ensure commitments outside of lifeguarding do not affect their performance on-duty, the installation of DDS can offer an extra level of support. A testimony from a health, safety and quality manager working within public pools has given credit towards its DDS for giving 'management and staff peace of mind with total coverage of the pool' (2016). As part of the recommendations for supervising pool areas with reduced visibility, HSG179 suggests the use of technology to help existing lifeguards. For example, hazards that reduce visibility such as glare can be reduced by DDS to offer underwater visibility regardless of the conditions.

Conversely, there are sources expressing more concerning views on DDS and their interaction with lifeguards. There are multiple sources stressing the importance of the accuracy of the technology and how this could have detrimental effects on how lifeguards carry out their work. Other concerns caused by false alarms are that they could cause lifeguards to ignore a genuine emergency and further, the literature suggests DDS risks giving a false sense of security to lifeguards (Sport England, 2011). Whilst these concerns are important to consider, there is a lack of evidence to support this.

6. Impact so far

Some DDS manufacturers report having detected and prevented 30 drowning incidents in public swimming pools (Poseidon, Drowning prevention, 2017) and claim to have over 240 installations (Pool and Spa Review, 2015). Meanwhile, other manufacturers give figures of having 120 complete installations and a further 22 in progress (SwimEye, 2018). Manufacturers believe that through embracing the technology, the industry will see technological improvements, reduced costs and enhanced pool safety (Swimming Pool Scene, 2017). To obtain a clear understanding of the impact of DDS is a difficult challenge. To use the number of reported DDS incidents as a reliable measure is problematic since there is currently no standardised way for all operators to report incidents, or no standardised method for classifying what constitutes an 'incident'. Furthermore, many of the sources for understanding impact come from DDS manufacturers rather than independent sources and it is difficult to discern whether lifeguards on duty would have performed their life-saving duties to the same effect regardless of whether the DDS raised an alarm. However, there have been several UK press reports that include reference to how DDS have raised the alarm in drowning scenarios, with this being followed by successful rescues.

Drowning detection systems are international, and so have reached various continents since their development and implementation. Some of the leading DDS manufacturers have distributors across Europe, the US and Asia including France, Belgium, Netherlands, Sweden, Norway, Germany, Russia, Canada, Australia, United Arab Emirates, Japan and China (Pool and Spa Review, 2015; Drowning Prevention, 2017; AngelEye, 2019; Sentag, 2016; PoseIdon 2019). Singapore's Minister for Culture, Community and Youth announced in 2019 that by 2020, DDS would be installed in eleven public swimming pools, and that they would be progressively implemented in a further 17 public competition pools.

Whilst there are recorded incidents where DDS have had positive impacts, not all have welcomed the used of DDS. There have been reported cases where the public have expressed concerns with the concept of being filmed underwater. There have been reports from a leisure centre in Kent and operators managing pools in Middlesbrough, Cleveland and Redcar who have received complaints from parents, concerned for their children being filmed underwater. Some feel that the use of underwater cameras are an invasion of privacy however, information can be found online from DDS manufacturers detailing that the images from the systems are subject to stringent data-protection laws. Footage and images are only viewed by background-checked lifeguards and are stored securely. Unless a recorded incident requires the relevant data to be kept for longer, the footage and images are deleted after five days (Kent Online, 2018; Mirror, 2018).

7. Conclusion

This literature review has discussed the various complexities of DDS within the health and safety landscape, as well as the wider implications of their use on the sport and leisure industry. It has also shed light on needed for more evidence in this area. From reviewing what literature currently exists on the topic, it is clear the evidence-base would benefit from qualitative research on the experiences of lifeguards and their interactions with DDS, as well as quantitative evidence showing DDS application to real-world scenarios. Claims expressing the risks of DDS negatively affecting lifeguarding performance should also be further investigated, and efforts made across the industry to ensure all publicly available information and guidance surrounding DDS is current and up-to-date. The Drowning Detection System Briefing note (Sport England, 2011) was published before documents such as HSG179 (4th edition), which is periodically updated, and ISO_20380 – operators should ensure that the sources they are using for DDS research do not draw from predated editions of health and safety law and guidance. Again, co-operation is required between all with an interest in the improvement of pool safety, to share data, information and learning on DDS, including but not restricted to results and findings from any DDS standards tests carried out. For by building and maintaining a robust evidence-base in this area, policy makers, operators, and suppliers can feel confident in their decision-making around the improvement of safety in public swimming pools.

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Overall Literature Review Summary

The literature found that whilst there were plenty of academic articles dedicated to the technology and design behind DDS in the fields of biometrics, computer science and electronic engineering, there was limited academic research investigating their application to real-world scenarios. This highlighted a clear gap in research, identifying the need and importance for independent, real-world scenario based research.

Defining DDS

The review found differing definitions and synonyms/acronyms used for DDS from different sources globally. They differed on the scope of what constitutes a DDS, which can be identified through how many features of surveillance they include. Most definitions included all three elements: 1) surveillance, 2) detection of a pool user in difficulty, and 3) raising an alarm. Other definitions were broader in scope including only features 1) or only 2) and 3).

Safety requirements & testing standards of DDS

The review of safety requirements for DDS drew from three core documents: The International Standard for Organisation's ISO_20380, the Health and Safety Executive's HSG179, and the German Institute for Standardisation and the German Association for Public Swimming pools' DGfdB R 94.15. They establish the safety requirements and guidance for DDS and the system's testing standards. The German testing standard was found to be more robust than the ISO testing standard and HSG179 standards on UK pool safety has a section on DDS. This gives guidance for operators and whilst other areas of HSG179 do not refer directly to standards of DDS, they specify standards that impact the performance of DDS. Operators must understand how their DDS interacts with UK pool standards and incorporate this into their PSOP.

Division of responsibility for operating DDS

Across the literature, there were four broad groups identified when researching the division of responsibility for the effective use of DDS. They are the DDS manufacturers, pool designers, pool operators and trained staff/lifeguards. Out of the four groups, operators have the most responsibility in ensuring their DDS is operated effectively and whilst trained staff and lifeguards have their own responsibilities, it is the overall responsibility of the operator to ensure they are competent and oversee staff training and organisation. It is important to identify areas of shared responsibility as co-operation between duty holders is important. All four groups needs to be clear about what is required of them and know where to go for help with areas outside of their responsibility.

Co-existence with lifeguarding

Whilst the literature on DDS was mostly in agreement such as on the risks and issues associated with DDS performance, the topic of co-existence with lifeguards was divisive. There is debate around whether DDS can be helpful or harmful towards lifeguarding practices and how DDS may change the landscape of traditional lifeguarding, as well as some disagreement on whether they serve as justification for reducing lifeguard numbers.

DDS impact so far

To use the number of reported DDS incidents as a reliable measure for understanding the impact DDS have had so far is problematic since there is currently no standardised way for all operators to report incidents. While several press articles report successful DDS detections and rescues, many of the sources for understanding the impact come from DDS manufacturers rather than independent sources and it is difficult to discern whether lifeguards on duty would have performed their life-saving duties to the same effect regardless of whether the DDS raised an alarm. Currently there are both positive and negative reports on the impact of DDS.

Summary

Moving forward, the review recommended that claims expressing the risks of DDS negatively affecting lifeguarding performance should be further investigated, and efforts are made across the industry to ensure all publicly available information and guidance surrounding DDS is current and up-to-date. Co-operation is required between all with an interest in the improvement of pool safety, to share data, information and learning on DDS, including but not restricted to results and findings from any DDS standards tests carried out. By building and maintaining a robust evidence-base in this area, policy makers, operators, and suppliers can feel confident in their decision-making around the improvement of safety in public swimming pools.

2. PRODUCT LANDSCAPE

1. Introduction

This document provides an overview of drowning detection systems (DDS) currently available on the global market. By providing a summary of the latest systems, this report aims to help the sport and leisure industry become more acquainted with the different types and qualities of each, and how they work. Though definitions of drowning detection systems vary in the literature, most outline three key elements which are; 1) surveillance, 2) detection, and 3) alarm raising. For the purpose of this report, the DDS explored were grouped according to whether they have one, two or all three of the defining elements. The characteristics of the following systems were explored:

Surveillance, Detection, and Alarm Raising (all 3 elements)

- SwimEye
- Poseidon
- AngelEye
- Poolview Plus
- Coral Manta (mainly designed for residential/ private pools)
- DiWatch (mainly designed for residential/ private pools)

Detection and Alarm Raising (2 elements)

- iSwimband
- Wave
- SenTAG
- BlueFox ST1
- SEAL

Surveillance (1 element)

- Zwembadcamera
- Poolview
- AngelEye view

2. Surveillance, Detection, and Alarm Raising

This type of DDS is the most common and most advanced in terms of technological capability. They are categorised as 'active' DDS, meaning they are designed to assist lifeguards in addressing the human limitations of traditional lifeguarding that make maintaining maximum, undisturbed vigilance at all times challenging. The surveillance component consists of cameras underwater, above water, or a combination of both. This is combined with image processing to give the DDS its second component of detection, making the system more robust. This is achieved through biometric artificial intelligence that analyses the human characteristics related to drowning. On screen images are converted to algorithms that can be used for pattern recognition. Some use object recognition software that can contrast standard images with infra-red images. Lastly, alarm raising is achieved through a combination of audio and visual cues that can be recognised both at poolside and remotely. Of the three types, this classification of DDS is most expensive. Price of systems is dependent on the requirements and specification of the pool.

SwimEye AS

Key Features:
>> Can be used in any pool type, with any construction material, in all pool shapes and sizes
>> Implemented during design stage or fitted retrospectively to existing pools

SwimEye AS is a Norwegian brand of DDS and has 120 completed installations across 6 different countries, with expansion to 12 new countries in progress. It can be used in both indoor and outdoor pools, and has been used in public pools, children's hospital pools, residential pools, water parks, sports pools, spa pools and specialised pools for diving. It works using underwater cameras that send the live images to be processed by their object recognition software, which then detects any possible drowning incidents. After a specified number of seconds have lapsed, lifeguards are alerted on the monitoring screen, as well as directly by portable pool radio where the incident location is referenced.

Poseidon

Key Features:
>> Uses overhead infra-red technology to monitor up to a depth of 2.5 metres
>> Uses underwater cameras where pools are more than 2.5 metres deep
>> Alarm set off time within 10 seconds

Poseidon is a French manufacturer, provided by the pool care solutions firm Maytronics. It is adaptable to different pool types, but is primarily used in public swimming pools. It uses a combination of both underwater and over water cameras to survey the pool. The underwater cameras use image converting algorithms whilst the above water dual cameras use an infra-red camera which is contrasted against a twinned regular camera. Factors such as texture and swimmers trajectories are monitored by this. The live images from the underwater cameras can be scanned on a screen located next to a lifeguard's chair, simultaneously showing all camera views. When a potential drowning incident is detected, after a specified number of seconds has lapsed, the system then triggers an audible alarm and visual alarms both on the monitor visible to the lifeguard and on the poolside, visible to all pool users. The on screen alarm has the capacity to locate the incident, indicating which part of the pool to address. Poseidon has over 230 installations.

AngelEye

Key Features:
>> Used with underwater surveillance, alone or combined with aerial cameras
>> In most cases, can be installed without draining the pool facility
>> Can alert lifeguards with special smart watches

AngelEye is an Italian DDS company and, can be used as a combination of both underwater and aerial cameras. As well as its main DDS product, it provides specialised DDS products such as AngelEye Hotel that has the typical requirements of hotels in mind and AngelEye Splash Down, specifically for the landing area of chute slides in water parks. Its surveillance system uses artificial intelligence to detect a possible drowning incident, and alert lifeguards via portable devices or a smart watch.

Poolview Plus

Key Features:
>> Uses both underwater and aerial cameras
>> Computer intelligence uses algorithms to detect incidents
>> Provides a simultaneous view to eliminate blind spots

Poolview Plus is a DDS manufacturer founded in the UK. Poolview Plus works through underwater cameras relaying real-time images to a poolside monitor for lifeguards, giving a full 360 degree view of the pool. Poolview advocates for the system to be integrated into the 10:20 scanning protocol allocating 4-5 seconds to scanning the monitor. The system can work around issues of traditional lifeguarding such as glare, and provides both audio and visual poolside alarms.

Coral Manta 3000

Key Features:
>> For residential swimming pools
>> Solar powered
>> Suitable for both above ground and ground-level pools

Coral Detection Systems are an Israeli start-up, manufacturers of the Coral Manta 3000. It is designed for residential pools and is solar powered, with the option to order an extra battery pack. It is less adaptable to varying pool shapes and sizes, working best with pool designs that are straight rather than curved, and have no hidden corner angles. This can be worked around by purchasing more units as the camera cannot capture views of more than 90 degree angles. It works by detecting suspicious activity through its underwater camera and alerting pool owners via a smart phone app and in-house alarm. It was developed for pools of up to 11 yards and designed to be on 24/7 so that users do not have to turn it on/ off and reactivate after each use.

DiWatch

Key Features:
>> For residential swimming pools
>> Uses an aerial camera
>> Can be self-installed without a technician needed

diWatch comes from a Spanish tech firm offering DDS surveillance for residential pools. Its detection system works by activating an alarm that can be triggered by either a person falling into the pool; suspected drowning movements; or a body immersed for an excessive amount of time. It activates an alarm using a mobile app and in-house alarm; is solar powered with a back-up supply; and can be self-installed without requiring a technician. It operates using an above-water aerial camera and has a viewing angle of 130 degrees.

3. Detection and Alarm Raising

This chapter summarises further 'active' DDS products with the capability to detect and raise an alarm for potential drownings. In general, products in this category are classed as 'wearable DDS'. Without the surveillance element explored in chapter 2, these types of DDS detect potential drownings through worn devices. Whilst they are cheaper and easier to install than the DDS listed in chapter 1, they do come with limitations as there is risk involved if a pool user takes off the device or if it falls off accidentally. Furthermore, the number of swimmers monitored is limited to the number of sensors available. An advantage to this however, is that wearable DDS can be used in either man made or natural swimming environments such as lakes or the sea and is not affected by issues such as bad lighting, glare and water clarity.

iSwimBand

Key Features:
>> Uses Bluetooth within a 30m range
>> Can be worn as a headband or wristband
>> Uses a low-power wireless sensor

iSwimband is a DDS from Aquatic Safety Concepts, based in the US. iSwimband uses a sensor that can detect when it is submerged in water. When activated along with the smartphone app, it alerts supervisors when it has been submerged for a set period of time. It can also be set to alert users when a non-swimmer (toddler for example) has entered the water. With this DDS, users can self-determine the amount of time before the sensor activates the alarm. A limitation is that the app is currently only available on the Apple store and the range for the sensor can be affected by environmental conditions. The maximum number of sensors that can be monitored at the same time is eight.

Wave

Key Features:
>> Sensor worn as headband
>> Can be set up within a few hours
>> Designed for easy transportation

Wave is an American brand of DDS. The product uses sensors worn as headbands around the back of swimmers heads. It is designed to be easily transported from location to location, giving it more flexibility than the DDS in chapter 1. It is also easy to set up and so would not disrupt pool scheduling. The system itself can operate on both battery and solar power and has the capability to run continuous self-evaluation tests to ensure the system is in working without defect. It works by sending a Bluetooth signal to a member who will be notified through their Staff Bracelet if a potential drowning incident is detected. The system configures a swimming area where the signal is reachable and has the capacity to notify swimmers if they swim beyond this. These are called Exit Detectors. To increase the swimming area, extra hubs and range extenders can be purchased. The trackers themselves are lightweight, unaffected by goggles or swim caps and float. Their battery is concealed and can last for approximately a year before they must be replaced, giving a warning when replacement is needed.

SenTAG

Key Features:
>> Sensor worn as wristband
>> Able to identify which pool area needs attention
>> Control Unit with easy user interface

SenTAG is a Swedish brand of DDS that comprises of a wristband sensor, pool wall receiver, wall mounted control unit and an alarm kept on the lifeguard. It works by continually monitoring depth (in terms of pressure) and time, and activates an alarm when pre-set thresholds are exceeded. When this occurs, the wristband sends a signal to the pool wall receiver, which communicates an alarm response to the wall mounted unit and the lifeguard's personal device. The alerts are audio and visual, and can display information. SenTAG wristband testing devices are also available where each wristband can be checked before use and installation of the system does not affect daily operation.

BlueFox ST1

Key Features:
>> Sensor worn as wristband
>> Wristband flashes to help lifeguards easily locate swimmer
>> Wristband releases a balloon to the surface of the water

BlueFox ST1 comes from a Swiss based company specialising in underwater technology and pool safety. It is designed for both natural and man made swimming environments and uses a wristband sensor, measuring depth and time lapsed underwater. When a potential drowning is detected, the wristband releases a balloon that floats to the surface. The balloon flashes and has a high-pitched audible alarm (100 decibels) to get the attention of a rescuer. The wristband itself also flashes, making the swimmer easier to locate. This is especially useful in natural swimming environments where the water clarity may be reduced. The device settings and alarm's parameters can be changed to suit swimmers in a variety of settings.

SEAL SwimSafe

Key Features:
>> Sensor worn around swimmers neck
>> Sensors can be adjusted to suit the swimmer's ability
>> Sensor uses radio frequency technology

SEAL SwimSafe comes from the tech start-up SEAL Innovation, based in the US. The sensor is a lightweight device, worn around the swimmer's neck. Using radio frequency technology, it activates an audio and visual alarm when it detects a potential drowning and alerts via a hub and via a guard band which is worn by the designated supervisor. The hub is portable and comes with a separate charger where the sensors can be recharged. One charge lasts up to six hours. Whilst the detection thresholds can be adjusted to suit the swimmer's ability, this cannot be changed by children. SwimSafe bands work up to a range of approximately 150 feet from the hub, and warns the swimmer if they swim outside of this range. If the warning is ignored, the beeping sounds for this escalates.

4. Surveillance

The final type of DDS is surveillance based only. These are known as 'passive' DDS and have the primary function of addressing the physical limitations of human surveillance that occur through issues such as glare and blind spots. The technology for this is much simpler than the DDS discussed in the above chapters and it is suitable only for man made swimming environments. For this type of DDS to be effective, it requires the supervision of a lifeguard or pool staff to monitor the camera images.

Zwembadcamera

Key Features:

>> Pool can stay open during installation
>> Images displayed either on monitor, tablet or smartphone
>> Can be installed in both public and private pools

Zwembadcamera is a Dutch brand of surveillance based DDS. Its name 'Zwembad' in Dutch translates to 'Swimming Pool', and the company has been installing underwater cameras worldwide for 15 years. It has developed an installation technique that enables the pool to stay open during installation and has been installed in public and private pools, as well as medical baths. The image can be displayed either on a monitor, tablet or smartphone and there are different display options such as having multiple images on one screen, different camera views on different screens or rotating different camera views on one screen.

Poolview

Key Features:

>> Above water and below water camera system
>> Poolside monitoring

Poolview is another product that comes from the same UK company behind Poolview Plus. It is essentially the Poolview Plus system but without the detection and alarm raising elements. It uses cameras both above and below the water and the images are then sent to a poolside monitor to be viewed by a lifeguard, in conjunction with the 10:20 system. This can help with surveillance in identifying an incident in the early stages.

AngelEye View

Key Features:

>> Surveillance with LED lighting system
>> Requires a home network or internet connection

AngelEye view is a variation of its counterpart listed in chapter 2. It is a combination of an LED-lighting system and underwater surveillance cameras. The cameras relay the images in real-time to a computer or smartphone, and has the capacity to save a video or take a snapshot. For this, the smartphone or computer must be connected to a home network or have an internet connection.

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https://www.timesofisrael.com/israeli-device-seeks-to-protect-swimmers-from-drowning-in-pools/
https://di-watch.com/en/info.html
http://www.premieraquatics.com/news/view/swimband
https://www.techguide.com.au/reviews/gadgets-reviews/new-iswimband-can-prevent-a-child-from-drowning/
https://www.wavedds.com/faq
https://www.sentag.com/products
http://www.poolview.co.uk/sentag
https://www.sentag.com/products/sentag-wristband-tester
http://www.poolview.co.uk/bluefox
https://www.bluefox-swiss.com/english/function/
https://www.bluefox-swiss.com/english/programming/
https://xconomy.com/raleigh-durham/2015/07/09/seal-innovation-dives-into-pool-safety-with-wearable-drowning-sensor/
https://www.sealswimsafe.com/
https://www.zwembadcamera.nl/en/totaalinstallatie
https://www.zwembadcamera.nl/en/het-product
http://www.poolview.co.uk/poolview
https://www.angeleye.it/page.php?id=45&page=48

3. TESTING OF CURRENT DDS AGAINST PUBLISHED STANDARDS

For this part of the project we organised and facilitated tests against ISO_20380 at four swimming pools, one with each of the different DDS. In order to undertake these tests in an empty pool, testing was carried out outside general public opening hours, either before the opening time of the pool or during a gap in the pool programme.

The ISO_20380 standard features a number of key areas:

- Documentation checks
- Trained staff awareness
- Hardware and software components
- Alarm set off time
- Areas covered
- False alarm rates
- Data communication and management
- Non detection test (in pool)
- Detection test, including accurate location of incident (in pool)

We had planned to include all the elements of testing, but were on occasions limited by staff awareness or staff knowledge. In some instances the staff members who had opened up the pool for us were not regular users of the system so were unable to supply all the required information. This did not impact the 'in pool' elements of the test as these were carried out without intervention from staff. For this reason the results will focus on this element of the test.

Carrying out the test: Non-Detection Test
For a full outline of the test procedure please see ISO_20380

To carry out this test, the point in the pool where the depth was 1.5 metres was located, with the remaining area of the pool (that had a depth less than 1.5 metres) divided equally into four quadrants. An individual was then instructed to stand at the centre of each of these quadrants, and additionally in the centre of the entire area for 40 seconds to ensure that the DDS did not detect this as a drowning incident and set off an alert. The results of this were recorded for each position. At one of the pools, the shallowest end of the pool was deeper than 1.5 metres so the non-detection test was not carried out.

This test was carried out with two people:
1. To stand in the pool at the relevant positions
2. To time 40 seconds using a stopwatch and record results

Carrying out the test: Detection Test
For a full outline of the test procedure please see ISO_20380

The detection test element of this task involves submerging a dummy of a specified design at a set number of positions in a pool, based on the pool dimensions. The same test dummy was used for each of the four pools to ensure consistency.

Before visiting each pool the dimensions of the pool were used to calculate the number of grid squares that would be required for the test. On arrival at the pool, a tape measure and cones were used to measure and mark out the appropriate distances to create a grid covering the required number of test areas.

The dummy was then attached to the end of a rope that was at least as long as the length and width of the pool. This rope was pre marked with the relevant measurements to divide the pool lengthways into the required number of grids (all pools tested were 25 metres long so this measurement did not change). Once the DDS had been switched on, the alarm set off time was checked. This time is used in the test as detections must be made within 2 seconds of this pre-programmed set off time. The percentage of the pool covered by darker tiles was calculated (e.g. 10%). The same percentage of tests were then carried out with the dummy 'on the line' (e.g. 6 tests out of a total of 60).

To carry out the test, the dummy was dropped in the centre of each of the grid squares, and a stopwatch was used to record the length of time from the moment the dummy was stationary, to the alarm or alert sounding. This time was then recorded. In order to move the dummy between positions, an assistant would stand at the end of each lane and pull the dummy along to the next position using the rope with pre marked measurements, with the markings on the poolside being used as an additional guide. Once a lane had been completed, the dummy was moved to the next lane and this procedure repeated until all the required lanes had been tested.

This test was carried out with four people:
1. To move the dummy from position to position using the rope.
2. To look at the dummy to determine when it was stationary and start the stopwatch, and to stop this when the alert/ alarm sounded.
3. To operate the DDS to cancel the alerts once they had sounded.
4. To oversee and ensure the dummy is being correctly moved from position to position, and to record results.

When summarising test results throughout this report, a range of time thresholds have been used to understand how the systems are performing over time. ***To be clear, the ISO_20380 standard specifies that there must be a detection rate of at least 80% within two seconds of the set off time.*** Any other time thresholds are included to establish more information on if systems are detecting before this, after this, or not at all. The additional results that have been included are for information only. The final threshold of 'detection within 30 seconds' is included as this was the time period that each test location was given before it was deemed to have not detected.

The alarm set off time is a predetermined value that is set by each manufacturer and is specific to each system and location. The ISO_20380 standard specifies that the set off time can be a maximum of 15 seconds. Two of the pools tested had a set off time of 10 seconds, and two had a set off time of 15 seconds.

The ISO standard defines a detection as ***"recognition of a total and prolonged immersion at the bottom of the pool basin of a stationary solid mass such as a person or object"***.

The ISO standard defines a false alarm as: ***"alarm set off for reasons other than detection".***

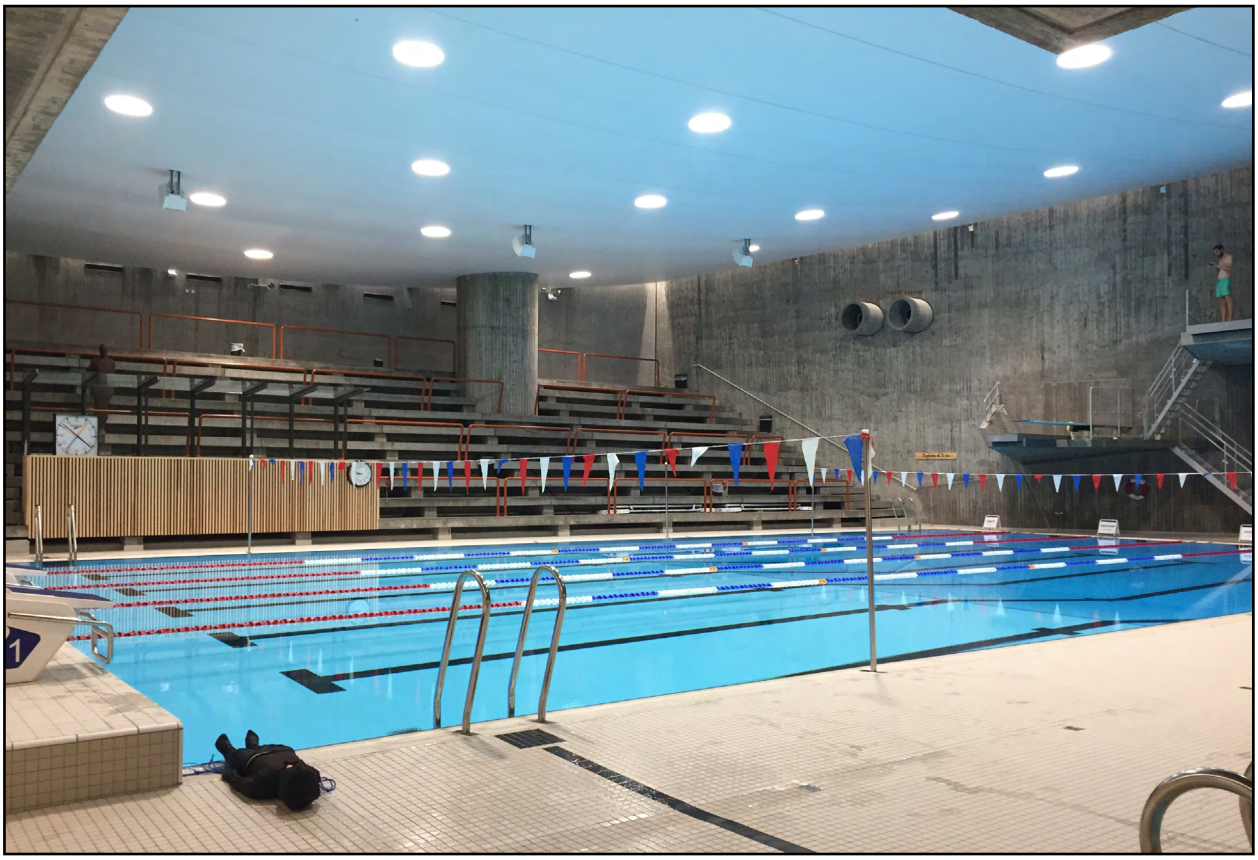
Characteristics of the pools

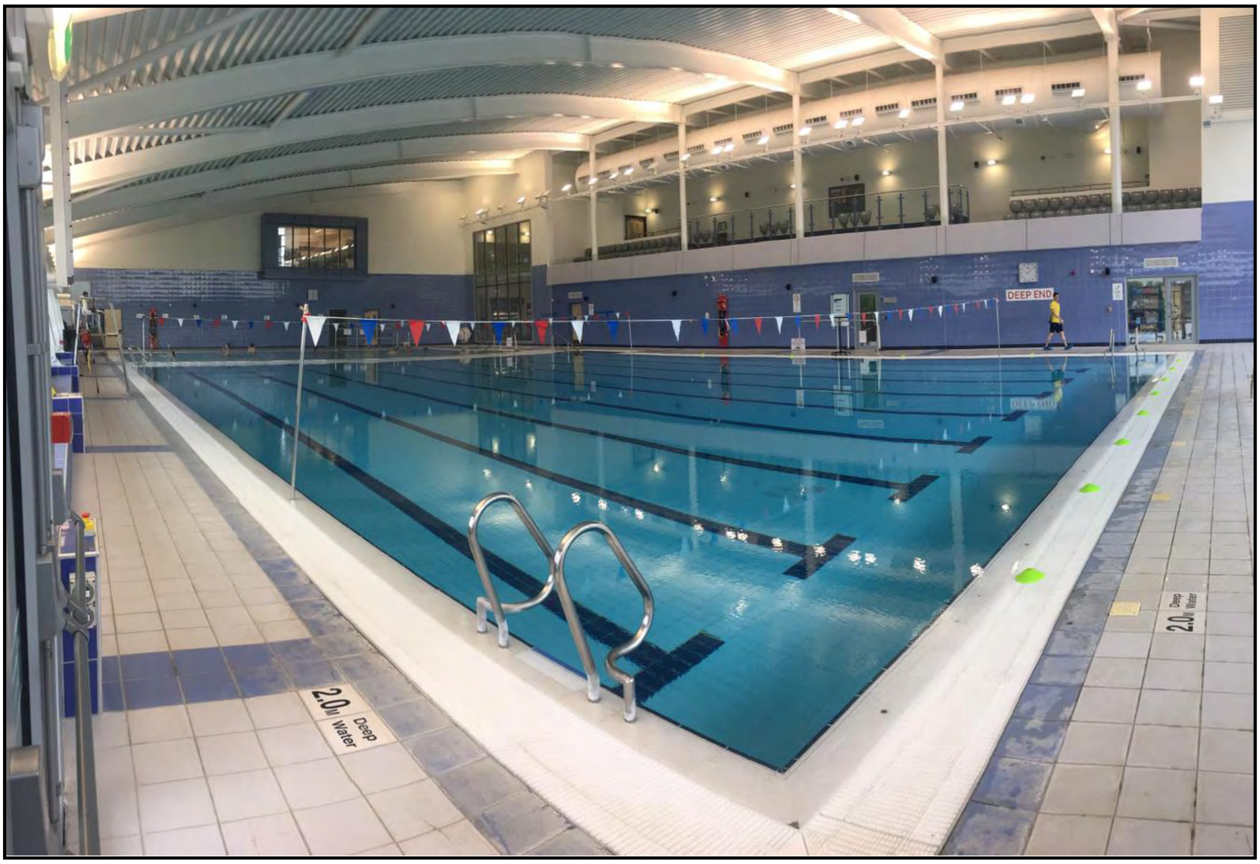
The table below lists the general characteristics of the pools that were tested (using the framework from section 5.4 of ISO_20380).

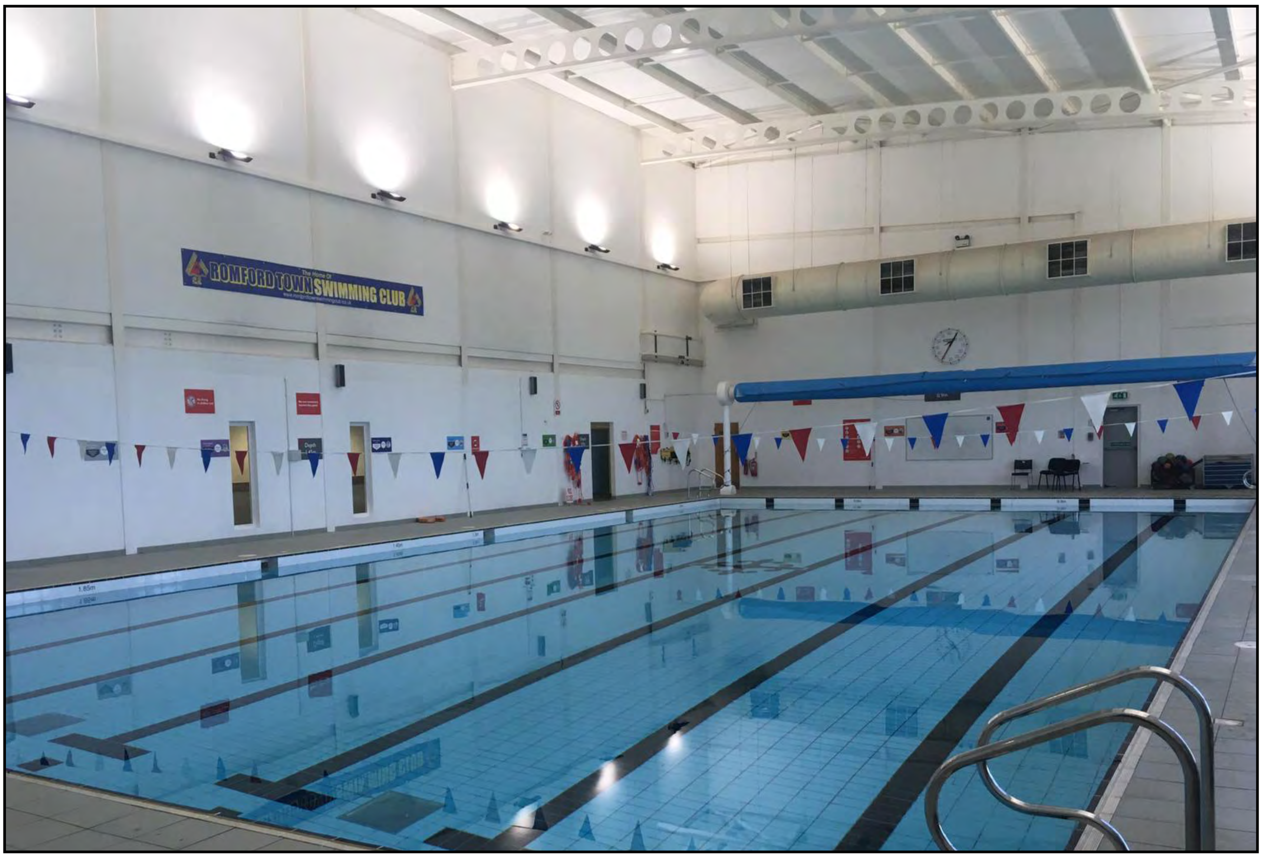
Pool	A	B	C	D
Description of the computer vision system for the detection of drowning accidents:				
number of underwater cameras	11	0	8	12
number of overhead cameras	2	8	0	0
Dimensions and type of wall and floor of pool				
length, in m	25	25	25	25
width, in m	18	17	14	14.5
minimum depth, in m	1.2	1	0.8	1.9
maximum depth, in m	2	2	1.8	4.5
floor type and colour	white tiles, dark blue lines	white tiles, dark blue lines and red markers	white tiles, dark blue lines and central pattern	white, not tiled, blue lines
wall type and colour	white tiles	white tiles	white tiles	white tiles
specific equipment (moveable floor, moveable walls, etc.)	steps down to pool	none	none	none
Lighting conditions at the time of the test				
average lighting level at pool basin surface (in lux)	396	189	231	195
natural lighting conditions	overcast	clear, dawn	clear	dark
pool water clarity at the time of the test (can pool markings on floor be seen?)	yes	yes	yes	yes

Photos from testing

Pools tested (randomised)



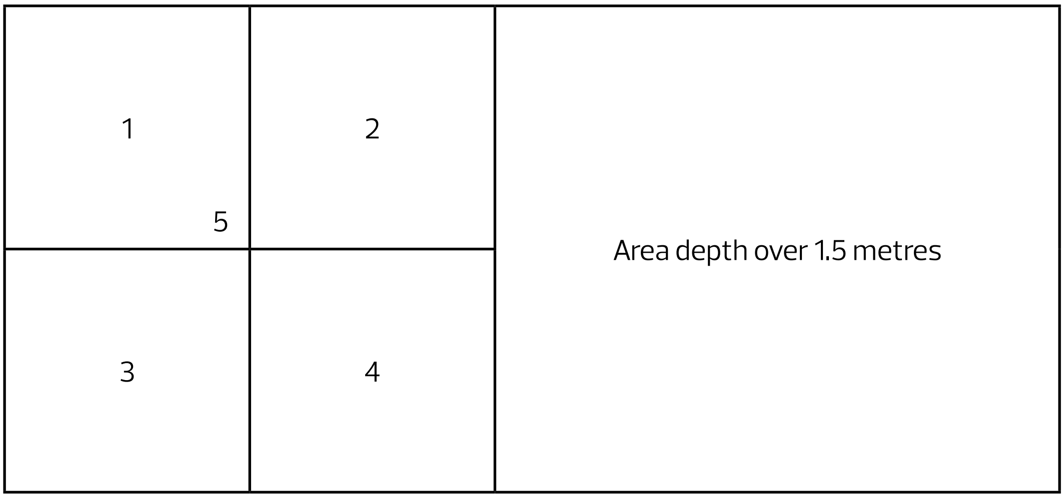

DEEP END
2.0m Deep Water
2.0m Deep Water


ROMFORD TOWN SWIMMING CLUB

Results: Non-Detection Test

In order to pass the non-detection test, a swimmer must stand in five positions in the pool for 40 seconds (where the pool is less than 1.5 metres). ISO_20380 states that the alarm must not go off on more than two out of five occasions. The table below shows that no detections were made in any of the five positions across the three pools tested (the fourth was over 1.5metres at its shallowest point).

Position	**1**	**2**	**3**	**4**	**5**	**Total non detection**
All Pools	ND x 3	ND x 3	ND x 3	ND x 3	ND x 3	15/15



Results: Detection Test

Results from all four pools have been aggregated and are reported below. The number of detections at each pool within the time parameters from the individual designated set off time have been added together and a total percentage calculated (for further detail on the ISO_20380 test procedure please refer to section 5.3 of the standard). The table below lists the number and percentage of detections within a range of time parameters from the set off time.

Total positions tested across four pools = 192

Detection time	**+/– 2 s**	**+/–3 s**	**+/– 4 s**	**+/–5 s**	**+ 2 s/ – 3 s**	**+ 2 s/ – 4 s**	**+ 2 s/ – 5 s**	**within 15s**	**within 30s**
Total detections	89	117	139	154	112	129	140	134	161
% Total detections	46%	61%	72%	80%	58%	67%	73%	70%	84%

Detection time	+/– 2 s	within 15s	within 30s
Minimum Value	31%	57%	62%
Maximum Value	60%	94%	100%

Test Specific Discussion

The non detection test was performed successfully at all three pools, with no detections.

For the detection test, the overall detection rate within the 2 second margin across the four pools was 46%. It should be noted that although this is below the ISO_20380 pass rate of 80%, there are a number of factors that should be considered when interpreting this result:

>> The rate of overall detections within 30 seconds was above this threshold at 84%. The difference between these figures was largely due to alerts being recorded ***too early*** e.g. more than 2 seconds before the set off time. The results show that when the threshold below the set off time is extended to five seconds (but the two second threshold over the set off time remains the same), the detection rate increases to 73%. There were a number of detections that occurred even earlier than five seconds before the set off time.

>> A second consideration is identifying the exact moment that the dummy becomes motionless on the bottom of the pool and starting the timing at the correct moment, which relies on the judgement of those carrying out the test. Starting timing too early, or too late, will have an impact on the time recorded. This has also been raised as an issue by a company who carry out tests against the standard and who have disregarded the 2 second threshold when calculating detection rates to allow for this error tolerance. When considering a five second allowance either side of the set off time, the required detection rate of 80% is reached across the pools.

4. TESTING OF CURRENT DDS AGAINST PUBLISHED STANDARDS (LIVE)

The current ISO_20380 standard mandates that DDS testing must be done in an empty pool. It is suggested that an optional, additional, test is used to monitor the system in operational conditions, but no guidelines or parameters are given for this test. To test the capabilities of DDS in the conditions they will actually be required, we developed a procedure to test them in live conditions.

This had to take into consideration the logistical complications of testing in a pool with swimmers and the general public present, but also be rigorous enough to replicate real life conditions. It is impractical to attempt to replicate the entire ISO_20380 test in live conditions. Instead a shortened and adapted version of this was used to determine how the system performs with the presence of other swimmers in the pool and the disturbance this causes, both in terms of physical bodies in the pool and movement of water.

The principles of testing were based upon ISO_20380, but with the understanding that a test of live conditions cannot be exactly reproducible due to a number of external factors. Therefore we developed the following test protocol which took this into consideration. This protocol is not designed to be as exhaustive as the mandatory ISO_20380 tests, but instead to provide a supplementary test that pools could carry out as an extension of their current testing. This was also a useful exercise to understand the ease with which tests can be carried out in live conditions and what can be learnt from this.

Test Procedure

Non-Detection Test:
This shall be carried out as per ISO_20380 in areas of the pool that are less than 1.5 metres in depth. This will follow the same method as the non-detection test specified in ISO_20380, with a swimmer standing in five positions across the area that is less than 1.5 metres. The other swimmers in the pool should continue with normal swimming activity whilst this test is being carried out. There shall be no limits to what constitutes 'normal' activity so this may include other swimmers resting or standing up elsewhere in the pool.

Detection Test:
As it is not feasible to undertake the same number of tests as the full ISO_20380 standard, the number of tests shall be set to 24, based on all testing taking place in 25 metre pools. This means the length of the pool should be divided by 6, and the width of the pool by 4. General testing principles and equipment will follow the method described in 5.3.5 ISO_20380. The dummy will be submerged in the centre of each of the test areas and the detection time for each of the test positions will be recorded. The required alert time of + / - 2 seconds from the designated set off time shall be used to determine if each test area reaches the standard required.

If possible, rope shall be used to place and retrieve the dummy around the positions that can be reached from the edge of the pool, and where required, a test assistant in the pool will move the dummy to the required positions. The assistant will be briefed on where to place the dummy and once placed, will take the role of a swimmer in the pool. As an additional test, four further locations will be tested. These will be the four corners of the pool (A-D on the diagram), with results for this being recorded as a 'yes' or 'no' for detection within 30 seconds.

Pool occupancy:
The test should take place once a minimum of 10 swimmers are present in the pool. Swimmers should be made aware that testing is being carried out, but that this will not impact their own swimming session.

Test diagram:

The diagram below gives the location of the 28 test positions that were used (24 grid squares plus four corners).

A 1	2	3	4	5	B 6
7	8	9	10	11	12
13	14	15	16	17	18
19 C	20	21	22	23	24 D

Carrying out the test: Detection Test

The test was carried out using a similar method to the non-live standard test, with the addition of an assistant in the pool to move the dummy from position to position as a rope could not be used due to swimmers being present in the pool. This method worked well and the test was able to be carried out with the minimum of disruption to those in the pool.

This test was carried out with four people, three on poolside and one in the pool:
1. In the pool to move the dummy from position to position.
2. To look at the dummy to determine when it was stationary and start the stopwatch, and to stop this when the alert/ alarm sounded.
3. To operate the DDS to cancel the alerts once they had sounded.
4. To oversee and guide the swimmer in the pool to ensure the dummy is being correctly moved from position to position, and to record results.

Results: Non-Detection Test

In order to pass the non-detection test, a swimmer must stand in five positions in the pool for 40 seconds (where the pool depth is less than 1.5 metres). ISO_20380 states: 'The swimmer shall not be detected more than twice for the total of the five positions.' The table below shows that one detection was made in the five positions across the three pools tested (the fourth was over 1.5metres at its shallowest point). Carrying out this test was slightly more difficult in live conditions as the assistant is required to stand stationary in a lane whilst the public are swimming in that lane.

Position	1	2	3	4	5	Total non detection
Pools	ND x 3	ND x 3	ND x 3	1 DETECTION, ND x 2	ND x 3	14/15

Results: Detection Test

The tables below show the results from testing, using the same analysis as the non-live test procedure.

Total positions tested across four pools = 96

Detection time	+/– 2 s	+/–3 s	+/– 4 s	+/–5 s	+ 2 s/ – 3 s	+ 2 s/ – 4 s	+ 2 s/– 5 s	within 15s	within 30s
Total positions	35	46	52	59	36	36	37	39	78
% Total detections	36%	48%	54%	62%	38%	38%	39%	41%	82%

Detection time	+/– 2 s	within 15s	within 30s
Minimum Value	13%	17%	46%
Maximum Value	83%	83%	100%

Detection time	within 30 seconds
Total corners (A–D)	9/16
Total detections (A–D)%	52%

Test Specific Discussion

Results from live testing showed one detection out of a total of fifteen in the non-detection test.

The percentage of total detections within 30 seconds was 82%. This was slightly below the figure of 84% for the non-live tests, but not noticeably so. The percentages detected within 2, 3, 4 and 5 seconds were however lower than the test in non live conditions. This suggests that detection is slower whilst there are swimmers in the pool, and highlights the importance of using live testing. The additional corner tests showed a detection rate of 52% out of the 16 possible detections, flagging a potential area where detection performance diminishes.

5. TESTING OF CURRENT DDS AGAINST ENHANCED STANDARD

Testing Background

DDS must currently perform to a standard as prescribed in ISO_20380. Phase 1 testing was carried out according to this standard. A number of shortfalls have been identified with this current standard. We have developed an 'enhanced' test protocol that is more rigorous and applicable to real life than the current test procedure.

The purpose of this stage of the project was to create a test protocol that we were able to use in phase 2 of the project testing. This in itself was a learning process and was undertaken with the awareness that further adaptations and amendments may be required after we have implemented the test and synthesised the learnings from this. The lack of current test protocols that include live testing meant that there was not a recognised benchmark to use to create an enhanced test protocol.

Areas where current standard was not deemed stringent enough:

>> Size of dummy: the current standard dictates that a specific size of dummy must be used, which is larger than a child.

>> Colour of dummy: the current standard does not specify what colour the dummy should be, meaning not all skin tones are represented in the testing stage.

>> Colour of swimsuit: the current standard dictates that a dark coloured swimsuit must be worn on the dummy.

>> Swimming attire: the current standard dictates that a female swimming costume is worn by the test dummy.

>> Test conditions: the current standard is carried out in an empty pool with no swimmers.

Test development

The current ISO_20380 test procedure takes around 90 minutes in a 25m x 17m pool (including set up time). This consists of 54 different test positions where the dummy is dropped in the pool and the response time from the DDS is subsequently recorded. The number of test positions is scaled according to pool size but for a 25 metre pool the test will take between 1 hour 15 minutes and 2 hours depending on pool width and number of testing lanes required.

Using two variables for each of the four changeable areas proposed above would present 16 different test scenarios if all were tested completely, totalling 768 test positions in a 25 x 17m pool. This volume of testing is clearly not feasible, especially if the test is to be reproducible.

With this knowledge in mind we sought to create a test protocol that would take these factors into consideration and would be more a more thorough test of the capabilities of the various DDS, but would be feasible and realistic to carry out within a 90 – 120 minute test window. With this in mind we presented a number of proposed solutions to the advisory group, and proceeded with a solution which focused on the main variables but was still stringent enough to test a number of different factors across the entire area of the pool.

Factors to test

>> Size of dummy: a small, lifelike dummy will be used for all tests (this is based upon a child aged approximately 8). This is in contrast to the 'torso' style dummy used in the standard test.

>> Colour of dummy: two dummies will be used for testing- one with a light skin tone and one with a dark skin tone. This is in contrast to the ISO standard lifesaving dummy which is typically yellow or orange.

>> Colour of swimsuit: two swimsuit variations will be used- light coloured swim clothing and dark coloured swim clothing. This is in contrast to the ISO standard which dictates dark coloured swim clothing must be worn.

>> Swimming attire: the dummy shall be tested wearing male swimming attire. This has been chosen as it will typically represent a smaller surface area of coverage than a female swimsuit.

>> Test conditions: an adaptation of the test for live conditions will be made.

Using this combination of factors allowed us to create four test 'conditions', which are combinations of the factors above.

Test Conditions

1. Small dummy, Dark skin tone, Dark male swimsuit
2. Small dummy, Dark skin tone, Light male swimsuit
3. Small dummy, Light skin tone, Dark male swimsuit
4. Small dummy, Light skin tone, Light male swimsuit

Number of tests

In order to create a test which will be feasible to carry out in a 90- 120 minute window, the number of test locations needs to be smaller than the scaling using in ISO_20380. For the purposes of phase 2 testing, which will be carried out in 25 metre pools, we will split the pool into 12 segments by dividing the length by 4 and the width by 3. In practice this will be approximately half the number of test cells from the standard test.

Each 'condition', or combination of factors, will be tested at each location giving a total of 48 tests. The same process as ISO_20380 will be used to carry out the test, with the proportionality of dark coloured pool tiles being calculated to ensure even distribution of tests.

As there is no standard for this, the test would not have a 'pass'/ 'fail' threshold. Instead results would be reported as a percentage of detections within certain time parameters, in the same way as the original test. This will allow comparison of results a) between the standard and enhanced protocol and b) between the different test conditions. By testing each condition in each location we would be able to determine if unusual results were due to the specifics of the grid square that was being tested, or the condition that was being tested.

Test locations

The locations that would be tested are shown in the diagram below (based on a 25m x 17m pool)

	6.25m			
5.67m	1	2	3	4
	5	6	7	8
	9	10	11	12

Carrying out the test

The test was carried out in a similar way to the standard test, with the clothes and skin tone of the dummy changed in between each of the sets of twelve tests. The test took around 90 minutes in total.

Characteristics of the pools

The table below lists the general characteristics of the pools that were tested (using the framework from section 5.4 of ISO_20380). It should be noted that for some pools the light readings changed between standard and live testing.

Pool	A	B	C	D
Lighting conditions at the time of the test				
Average lighting level at pool basin surface (in lux)	383	111	231	178
Natural lighting conditions	dark	dark	clear	dark
Pool water clarity at the time of the test (can pool markings on floor be seen?)	yes	yes	yes	yes

Results: Detection Test

The tables below show the results from testing, aggregated across all four pools.

Total positions tested across four pools = 192
Total positions tested across each condition = 48

Detection time	**+/– 2 s**	**+/–3 s**	**+/– 4 s**	**+/–5 s**	**+ 2 s/ – 3 s**	**+ 2 s/ – 4 s**	**+ 2 s/ – 5 s**	**within 15s**	**within 30s**
A. Small dummy, Dark skin tone, Dark male swimsuit	44%	63%	69%	79%	63%	63%	71%	73%	88%
B. Small dummy, Dark skin tone, Light male swimsuit	42%	54%	58%	67%	48%	52%	58%	71%	83%
C. Small dummy, Light skin tone, Dark male swimsuit	54%	60%	67%	67%	54%	58%	58%	67%	81%
D. Small dummy, Light skin tone, Light male swimsuit	52%	69%	69%	77%	63%	63%	65%	67%	90%
TOTAL– OVERALL	48%	61%	66%	72%	57%	59%	63%	6	85%

Test Specific Discussion

As there is no published standard for enhanced testing, analysis was focused on comparison between standard and enhanced results, and the difference between the four dummy conditions. Overall detection within 30 seconds across all four dummy conditions was 85%. This was slightly higher than the rate of 84% for the non-enhanced test. This is positive as it suggests that the systems work as well at detecting a smaller, more lifelike dummy. The detection rate for each of the time thresholds was similar, or slightly higher in the enhanced test. Detection success within 30 seconds varied across the dummy conditions from 81% to 90%, with the light-light combination scoring highest. There was no obvious trend in the performance of the different dummy conditions within the time thresholds, with the light-dark combination having the lowest overall detection within 30 seconds (81%) but the highest within the 2 second threshold (54%).

6. TESTING OF CURRENT DDS AGAINST ENHANCED STANDARD (LIVE)

Background

Once the enhanced tests had been carried out, an adapted version was carried out in 'live' conditions, in a similar way to how the live testing for the standard protocol was carried out. For the live tests, as four different combinations of dummy factors were being used, the test grid was reduced in size further to create a feasible test procedure that could be carried out within a reasonable time frame.

As with both phase one of testing, and the non-live standard test, the principles of testing were based upon ISO_20380, but with the understanding that a test of live conditions cannot be exactly reproducible due to the number of external factors.

Test Procedure

Non-Detection Test:
As this had already been carried out in the non-live procedure this was not repeated.

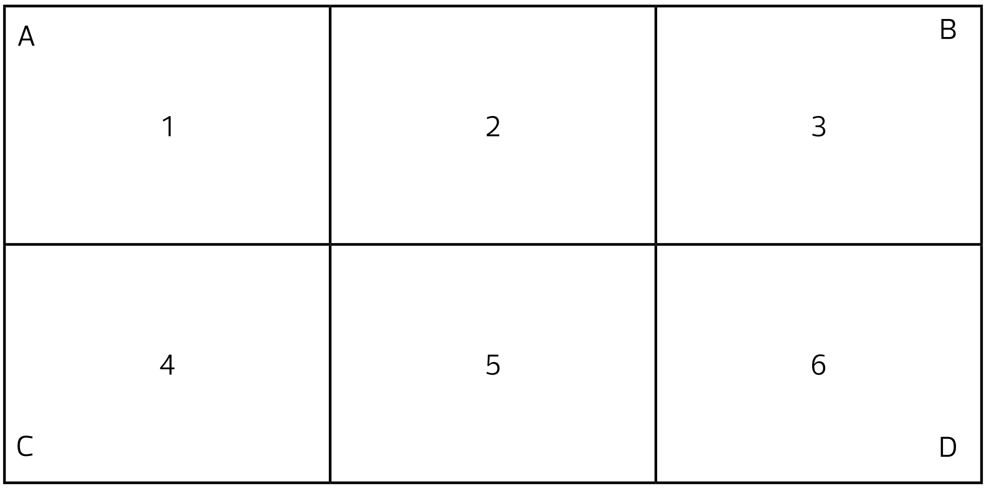
Detection Test:
As it was not feasible to undertake the same number of tests as the full enhanced standard, as this would have resulted in a test that would take upwards of four hours, the number of tests was set to 6, based on testing all four combinations once at each location, and all testing taking place in 25 metre pools. This meant the length of the pool should be divided by 3, and the width of the pool by 2. General testing principles and equipment followed the method described in 5.3.5 ISO_20380. The dummy was submerged in the centre of each of the areas and the detection time for each of the test positions recorded.

Where possible, rope was used to place and retrieve the dummy around the positions that can be reached from the edge of the pool, but where required, a test assistant in the pool moved the dummy between positions. The assistant was briefed on where to place the dummy and whilst not placing the dummy took the role of a swimmer in the pool.

In addition to these 24 tests, an extra test would be carried out at each corner of the pool, for each condition, totalling an extra 16 tests. This is in response to feedback from phase 1 of testing. The results of this will simply be reported as the number of detections within 30 seconds (out of 4).

Pool occupancy:
The test should not begin without 10 swimmers being present in the pool. Swimmers should be made aware that testing is being carried out, but that this will not impact their own swimming session.

Test diagram:
The diagram below gives the location of the 6 test positions that were used for live testing for each of the four dummy combinations (plus the four corners marked A-D).



Results: Detection Test

The table below shows the results from testing, using the same analysis as the non-live test procedure.

Total positions tested across four pools = 96

Total positions tested across each condition = 24

Detection time	+/– 2 s	+/–3 s	+/– 4 s	+/–5 s	+ 2 s/ – 3 s	+ 2 s/ – 4 s	+ 2 s/ – 5 s	within 15s	within 30s
A. Small dummy, Dark skin tone, Dark male swimsuit	50%	58%	58%	63%	54%	54%	54%	46%	92%
B. Small dummy, Dark skin tone, Light male swimsuit	13%	25%	38%	42%	17%	21%	25%	42%	67%
C. Small dummy, Light skin tone, Dark male swimsuit	17%	25%	29%	29%	17%	17%	17%	25%	58%
D. Small dummy, Light skin tone, Light male swimsuit	8%	13%	21%	21%	13%	13%	13%	21%	46%
TOTAL	22%	30%	36%	39%	25%	26%	27%	33%	66%

Detection time (corners)	within 30 seconds	within 30 seconds
A. Small dummy, Dark skin tone, Dark male swimsuit	6	38%
B. Small dummy, Dark skin tone, Light male swimsuit	6	38%
C. Small dummy, Light skin tone, Dark male swimsuit	9	56%
D. Small dummy, Light skin tone, Light male swimsuit	4	25%
TOTAL	25	52%

Test Specific Discussion

Overall detection within 30 seconds across all four dummy conditions was 66%. There was some variation in performance between the four conditions, with both darker skin tone conditions achieving higher detection percentages within 30 seconds than the lighter conditions. This is not the same outcome as was seen in the non-live version of this test, suggesting these outcomes and particular detection failures are more likely to be down to individual circumstances rather than the swim wear type or skin tone of the dummy.

The percentage of detections within each of the time thresholds was lower than the non-live test, with a higher drop off seen here than in the standard tests. The results show that live conditions had a greater impact on performance for the enhanced procedure than for the standard procedure, highlighting the importance of undertaking live testing.

In the additional tests that were carried out in the corners of the pools, the overall detection within 30 seconds was 52%, the same as the standard dummy, suggesting that the low detection is due to technological difficulties with recognising these areas rather than the size, type, or shape of dummy tested.

7. SUMMARY OF TESTING

Difference between standard and enhanced test (non-live)

There was little difference in overall detection rate (within 30 seconds) between the standard and enhanced test. The detection rates within 2 seconds were also similar. At one pool, there was a series of performance issues with the standard test which will have brought down the overall average of the tests. Despite this, the similarity in results between the standard and enhanced tests suggests that the systems are able to detect the smaller dummy / manikin with more lifelike features without deterioration in performance which is a positive sign, and also suggests that this dummy could be adopted for all testing.

Difference between live and non-live tests

For the standard test in live conditions, there was little overall decline in overall detections within 30 seconds, but the detections within each of the shorter time thresholds reduced. For the enhanced test in live conditions, there was a larger decline both in overall 30 second detection performance and in each time threshold. This suggests that system performance can decline when detecting in live conditions and emphasises the importance of including some form of live testing into test routines and procedures. The bigger performance decline seen in the enhanced version suggests this is a more stringent test of the DDS and this is the dummy version that should be used to ensure the most rigorous and life like conditions are being replicated.

Difference between the four dummy conditions

Across the enhanced tests, there was not a consistent pattern in terms of performance of the four different dummy conditions. There was a larger range of detection performances in the live test, but the dummy conditions with the highest detection rates here were different to those that performed best in the non-live test. Performance was higher overall on the non-live test. These results suggest that the most stringent test of DDS came from using the smaller dummy with more lifelike features in live conditions. The skin tone and swim wear colour combination was not a significant factor in the test results.

Lack of availability of test dummies

Another important consideration was the difficulty in locating a dark coloured test dummy– after thorough research no product could be found and a proxy had to be created by covering a light coloured dummy in dark coloured clothing. This was not an ideal solution and added additional tasks to the test procedure. Whilst the skin tone was not a significant factor in detection performance in this project, the lack of diversity in test dummies could prove to be problematic for other tests or training exercises.

Areas where performance of systems was lower than average

Whilst carrying out the tests there were some areas that performed worse than others in terms of detection. The additional tests carried out on corners showed that this area (which is not part of the standard test) performed worse than the rest of the pool, with 52% and 48% of detections within 30 seconds in the standard and enhanced tests. This is an area that may require further manufacturer development in order to bring it up to the same standard as the main pool area. Where pools had a slope from the shallow to deep end, the detection rate was lower when the dummy was placed directly onto the slope.

Awareness of the test and ease of carrying it out

The ISO_20380 test took around 90–120 minutes to carry out depending on pool size. This included time to set out cones to mark the grids and to take light readings. The pool test required a minimum of three people to be able to carry it out easily, although four was preferable and enabled detections to be tracked and recorded more efficiently. In the pools we visited there was limited awareness of what the test was, with some pools not having any recollection of this version of the test being carried out before. This suggests that the 6 monthly full test required by the standard is not being uniformly carried out across all pools.

Carrying out live tests

We designed the live test protocol with the difficulties associated with real life testing in mind, and found a solution which we felt would be able to be carried out with relative ease and minimal disruption to swimmers in the pool, whilst still gathering sufficient data to be able to draw conclusions. In practice, live testing worked well and by having a designated swimmer in the pool to move the dummy around we were able to carry out the tests quickly and efficiently without having to change the usual lane swimming pattern of the pool. The only difficulties that were encountered were when the pool was extremely deep (e.g. more than two metres) which meant picking up the dummy from the bottom of the pool was not possible, and this was instead attached to a short rope.

8. LIFEGUARD SURVEY

Background

This was an area of work that was outside the original scope of the project, but following the first advisory group meeting it became apparent that it was important to gather opinion from as many lifeguards as possible, and a survey would have a far wider reach than the focus groups that were planned. As such this piece of work was added in as an addition to the original work plan, with the idea that the findings from the survey would also formulate the themes that would be discussed at the subsequent lifeguard focus groups.

An online survey was designed and created following extensive collaboration with RLSS and the operator group involved in the project. The survey was designed for all lifeguards, regardless of whether they had used DDS themselves. The topics that were covered included:

- Lifeguard age and experience
- Perceptions of challenges in lifeguarding role
- Use of DDS (if relevant)
- Perceptions of DDS
- Pool scanning and the 10:20 protocol

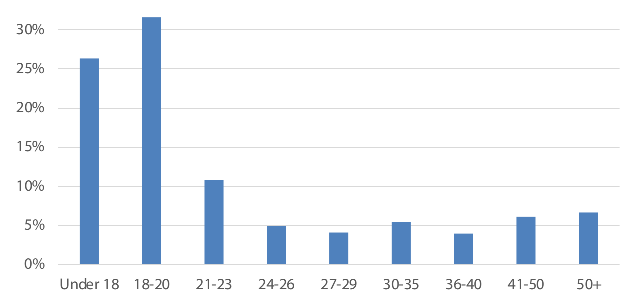
The survey was incentivised with a prize draw for two £100 Amazon vouchers. The RLSS kindly assisted in the distribution of this by emailing the link out to their network of qualified lifeguards. The survey was open for two weeks in September, and these actions enabled us to collect over 6,000 responses.

Results

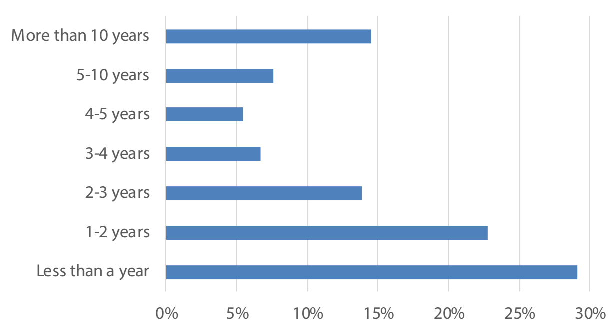
General Characteristics of Respondents

The majority of respondents fell into younger age groups, with 58% aged either under 18 or 18–20. This corresponded with most of the lifeguards having been qualified for less than a year (29%). For those aged over 20 there was a reasonably even split amongst the age groups. 23% of lifeguards had been working for between one and two years, meaning that in total over half of respondents had less than two years experience. 15% of respondents were at the opposite end of the scale, having lifeguarded for over ten years. The difference in responses between younger and older lifeguards, and those with more or less experience are analysed later in this section.

How old are you?



How long have you been lifeguarding?



Challenges associated with lifeguarding

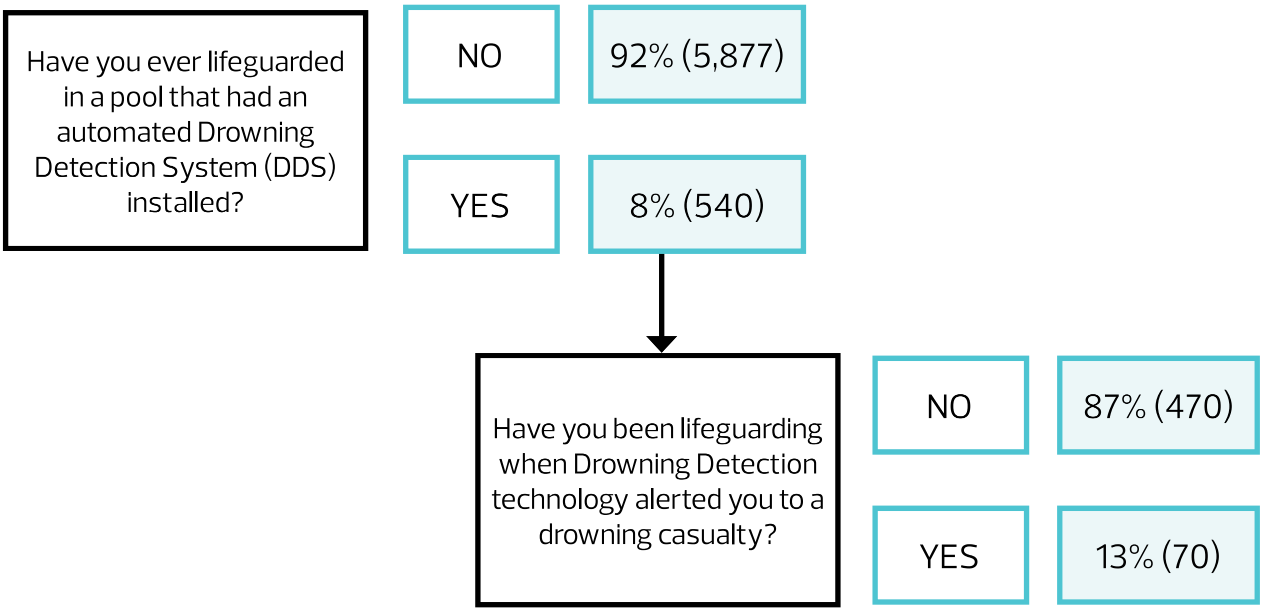
When asked about the challenges associated with lifeguarding, there were some key factors that made the lifeguards role both easier and harder. Respondents were asked to consider the impact of different potential challenges or facilitators for lifeguarding. Being able to take regular breaks was the element that the highest percentage of people said made the job easier or a little easier, with nearly everyone (93%) selecting these options. Having very few pool users also scored high in this respect, with 81% of respondents. In terms of what made their job harder, there was five factors that over 80% of respondents felt made their job harder or a little harder– glare from sunlight (96%), lots of pool users (92%), reflection onto the water (89%), being more tired than normal (88%) and poor lighting in the pool area (82%).

	EASIER/ LITTLE EASIER
Being able to take regular breaks	93%
Very few pool users (pool is very quiet)	81%
Carrying out other activities whilst on shift e.g. cleaning the pool area	30%
Poor lighting in the pool area	5%
Customers talking to you whilst you are on duty	2%
Noisy environment	1%
Lots of pool users (pool is very busy)	1%
Reflection of something onto the water	1%
Glare from sunlight	0%
If you are more tired than normal	0%

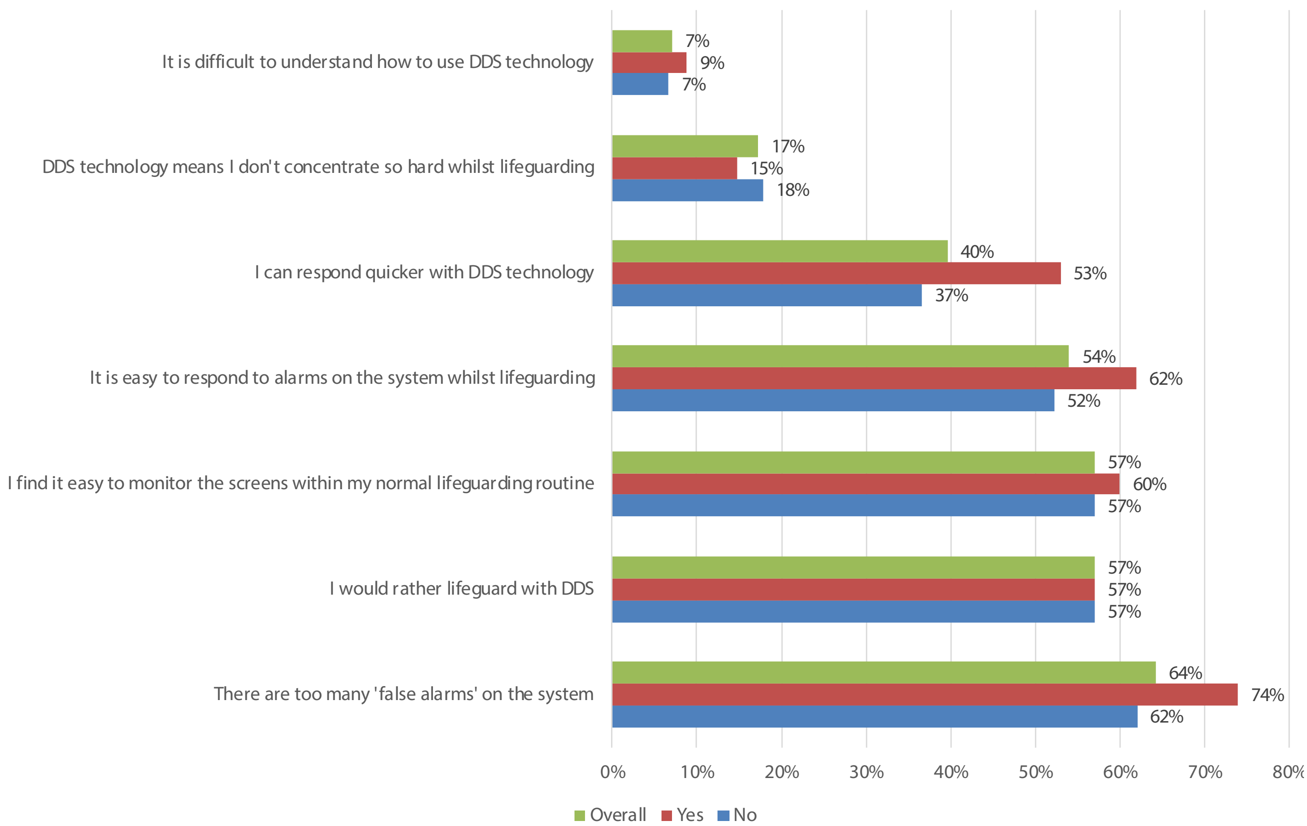
	HARDER/ LITTLE HARDER
Glare from sunlight	96%
Lots of pool users (pool is very busy)	92%
Reflection of something onto the water	89%
If you are more tired than normal	88%
Poor lighting in the pool area	82%
Customers talking to you whilst you are on duty	78%
Noisy environment	60%
Carrying out other activities whilst on shift e.g. cleaning the pool area	34%
Very few pool users (pool is very quiet)	7%
Being able to take regular breaks	2%

Use of DDS

The survey asked if lifeguards had used DDS before (a detailed explanation of this was provided). Those that answered 'Yes' were also asked if they had been alerted to an incident involving a drowning casualty whilst using DDS.



All respondents were then asked to state their level of agreement with a number of statements around DDS. The graph below shows the percentage who answered 'agree' or 'strongly agree' in green, and then split by their answer to the casualty incident question with yes in red and no in blue.



At this point in the survey lifeguards were invited to give their thoughts on the positive and negative elements of using DDS. The associated free text responses were analysed using NVivo software which highlights key themes and the frequency of occurrence of these. The section below details the themes that were commented on most frequently for each question and provides some direct quotes from respondents.

What is the best thing about having a DDS to work with?

Extra help:

For when the pool is busy
For human error/ limitations
For making sure everyone is covered
For accuracy
For specific activities

Improved view:

Glare issues
Blind spots
Water clarity issues

Direct Quotes

"Gives you another view in the pool so helps to reduce blind spots especially when there is glare"
"The false alarms also keep you focussed on the pool and you have an extra set of eyes"
"It also alerts other staff in the centre quicker and saves me the time of having to radio"
"Feel more confident about safety of swimmers"
"Alerts you to a casualty that you may not see with the naked eye. e.g. if the pool is crowded"
"It gives you peace of mind"
"It's great in busy conditions"
"It records events so that if after reflection is required, it can be provided"
"It allows other lifeguards in the leisure area to know of the situation so they can either quickly respond with help and/or calm other swimmers"

What is the worst thing about having a DDS to work with?

False alarms:

Pool tiles
Glare and lighting
Pool users standing still
Slow swimmers
Dark skin tones

Distraction/ over reliance:

Takes attention away from pool
Can lead to complacency

Direct Quotes

"I don't feel the need to pay as much attention"
"Have to sit in one place and can't move to enforce rules/ask if customers are ok"
"It often freezes up and no matter how much you are /panicking/ and hitting the cancel button, it automatically sets off the evacuation alarm anyway."
"Hard to incorporate this into our scanning system. 5 seconds to scan pool 5 seconds to scan screen is sometimes not enough"
"There are also a number of blind spots, kids like to play with them (blocking them) and appear to need cleaning regularly"
"False alarms, e.g. alerting you to things like the black lines on the bottom of the pool and after pushing the cancel button it alerts you to the same thing several times taking your focus away from the pool"

Additional feedback from users of DDS

In order to obtain more feedback from users of DDS a free text question was included in the survey, inviting respondents to give any comments about their experience of lifeguarding with DDS. The feedback from this question was extremely varied and covered a wide range of topics. These have been grouped below according to the sentiment expressed.

Positive

"Can not emphasise the added benefit of the reassurance to our team"

"Since installing from both a lifeguard and management point of view it's invaluable and would highly recommend to anyone to install to assist the lifeguard team but not to replace"

"I found it very useful and didn't realise how much we rely on it until it broke for two weeks. It was manic and meant we needed more lifeguards available on each shift even from 04:45"

"Fully support any actions and activities to help me in my role, DDS can only be positive"

Mixed/ neutral

"They are helpful but the detecting isn't very good"

"They're good and bad"

"The algorithm needs to be improved to differentiate different type of swimmers in different type of pools"

"Rarely had a genuine activation that hasn't already been seen/avoided however since using DDS, its not made much difference"

Negative

"Concern about the number of false alarms... lifeguards get frustrated with the system and assume it is always wrong"

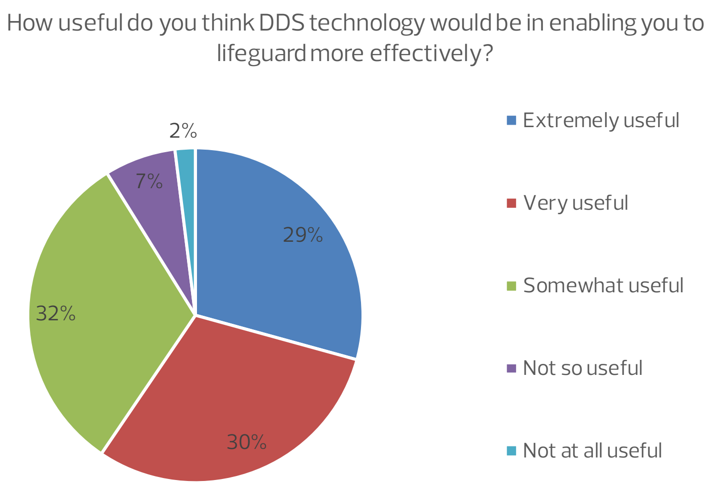
"Lifeguards rely on the system and become lazy with standard lifeguarding practices"

"The reset button constantly breaks. It notices way to many drowning tiles"

"Greatly hinders how effective a lifeguard can be"

Perceived understanding of DDS from those who had not used it

For lifeguards who did not have experience of working in a pool where DDS technology was installed (92% of total respondents), a question was included to try and understand what their perception of the technology was. The responses to this question indicated that there was a generally positive attitude towards the use of DDS, with 29% of respondents indicating they would find this 'extremely useful' in lifeguarding more effectively and a further 30% saying it would be 'very useful'.



To gain further insight into what the general attitude towards DDS was by those who had not used it, respondents were asked to think about what they perceived the potential benefits and drawbacks would be. These free text responses were again analysed to draw out the key themes that occurred most frequently.

What do you **think** would be the best thing about using DDS?

Another level of reassurance:

Extra pair of eyes
Faster than human reaction
Could save lives

Help with blind spots:

Can cover the whole pool
Can give a clear underwater view

What do you **think** would be the worst thing about using DDS?

Distraction:

Could take attention away from pool
Alarms could be disruptive
Could be false alarms

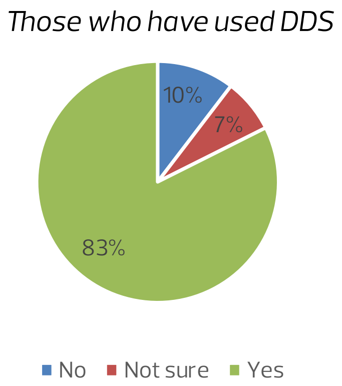
Over reliance:

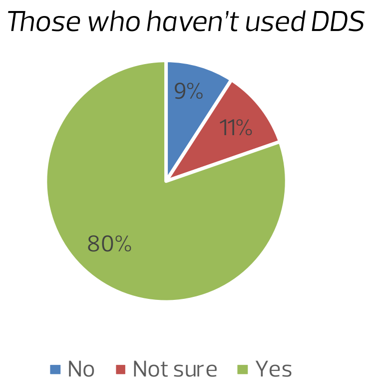
Could lead to complacency
Could detract from the job role

Lifeguarding using the 10:20 guidance

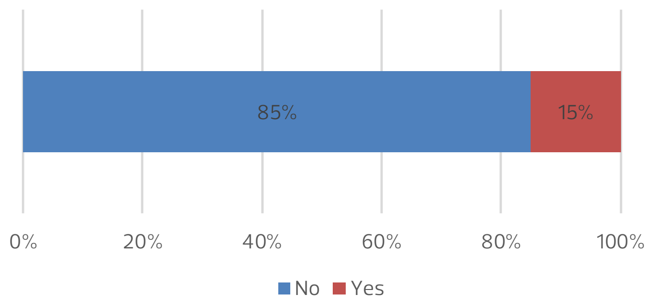
All respondents were asked about their views on the 10:20 guidance for pool scanning. The graphs below show the responses when asked if they thought it worked well for lifeguarding. The responses to this were largely positive, with 83% of those who had used DDS answering yes, and 80% of those who had not used DDS also answering yes.

Do you feel that scanning your zone for 10 seconds, every 10 seconds works well for lifeguarding?





Has the 10:20 system ever been adapted for you to use with DDS?



Those who answered yes to this question were asked to give further details. Most of the adaptations involved changing the time ratios used for scanning and reacting, including 5:5 most frequently but also 2:8, 3:7 and 4:6.

Ideas for other scanning options

Respondents were asked what system they would use if they were going to develop a new system for scanning a pool. Many responses were in support of 10:20 with a large percentage of respondents not feeling the need to suggest an alternative.

The alternatives that were suggested are grouped below.

Different time ratios:
>> 5:5
>> 20:20
> >15:20
>> Including screen time specifically in ratio

Different scanning patterns:
>> Scan above water and below water separately
>> Use a zig-zag scanning pattern
>> Scan overlapping areas
>> Scan in lanes

Concentrating on higher risk elements:
>> Concentrate on at risk swimmers
>> Spend more time on areas with hazards
>> Scan the area slower

Alternative ideas:
>> Use headcounts
>> Use underwater cameras
>> Use heart rate trackers

Additional feedback from the survey

The final part of the survey offered the chance for respondents to give any more feedback on lifeguarding generally. As could be expected from a broad question a wide range of topics were covered. The main themes covered have been summarised into groupings below.

Positive aspects of lifeguarding:

>> Offered a rewarding job
>> Teamwork is important
>> Strong sense of unity within team
>> Great experiences of lifeguarding

Training:

>> Some aspects of training could be improved
>> A better mechanism for raising anonymous concerns is needed

Division of responsibilty:

>> Role of parents not always clear
>> Role of parents not always enforced

Pay:

>> Generally felt level of pay does not accurately reflect job role
>> Level of pay inconsistent between staff

Time on poolside:

>> Emphasised importance of regular breaks
>> Understaffing makes job much harder
>> Rotation system received favourable feedback

Pool environment:

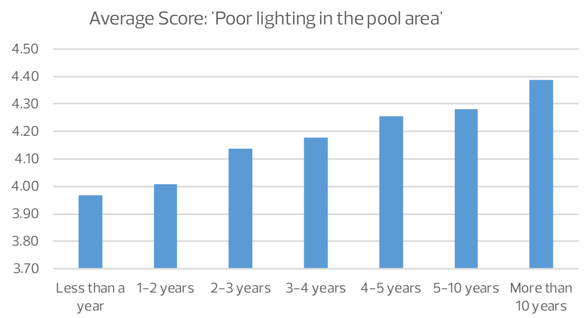
>> Poolside is often too hot which makes job harder
>> This can lead to concentration loss

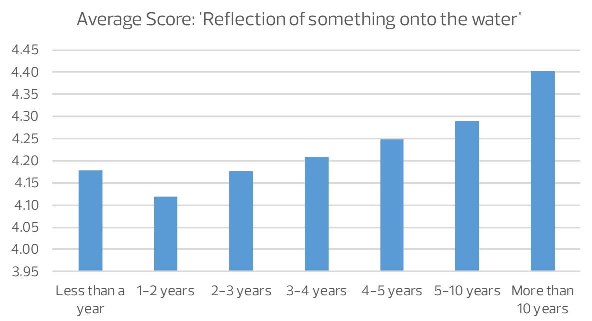
Does age or experience influence attitudes towards lifeguarding and technology?

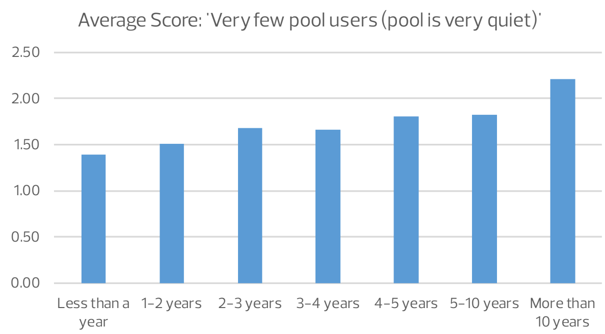
To see if the age of a lifeguard or their experience in the job had an impact on how they answered different questions, further analysis was undertaken on some responses from the survey. When looking at the list of factors that made lifeguarding harder or easier, there was no conclusive evidence to suggest that the age or experience level of a lifeguard had an impact on their answers.

This analysis was done by assigning each response for likert scale questions in the section with a score, where 1 is 'makes it easier' and 5 is 'makes it harder'. From this, an average was calculated for each age group and length of experience. The three graphs below show the factors for which there was a noticeable trend, although this was the opposite to the trend that would seem most intuitive. Both older and more experienced lifeguards scored higher on average when rating the difficulty of the impact of poor lighting, reflection onto the water and a quiet pool. There was no trend displayed for the remaining factors.

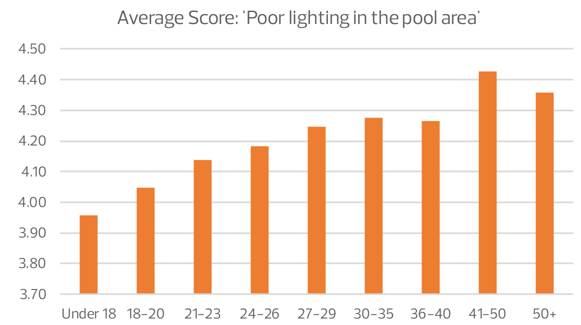
Factors by length of experience

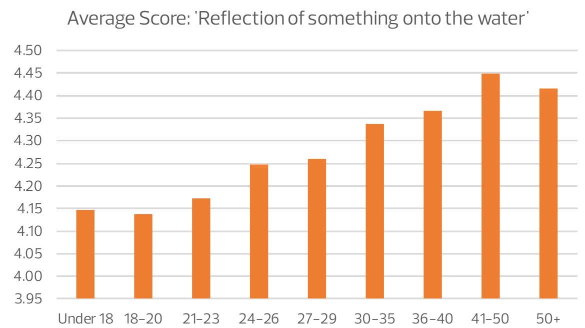


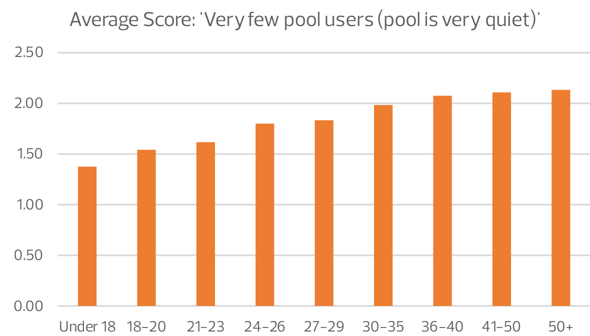




Factors by age







9. LIFEGUARD FOCUS GROUPS

The original project plan included undertaking focus groups with lifeguards, to enable us to gather first hand information about how they viewed their role and what could make it easier. These groups were planned to include a wide range of participants, including both lifeguards who had used DDS and those who hadn't. With the addition of the lifeguard survey to the project, we were also able to use the focus groups to further explore some of the key themes that emerged from the analysis of responses to this.

Two focus groups were conducted with a mixture of individuals at each:

>> Lifeguards who worked at a pool that had underwater CCTV but not a full DDS
>> Lifeguards who worked at a pool with DDS
>> Lifeguards who had not used underwater cameras or DDS

These focus groups were carried out either at the home pool of the lifeguard, or at the ukactive head office. Participants were offered a gift voucher in return for giving up their time. Those taking part signed a consent form to allow us to anonymously analyse their contributions. The focus groups lasted between 45 and 60 minutes and were guided by the key discussion points mentioned below, however dialogue was led by the lifeguards wherever possible to allow us to gather unprompted thoughts and opinions.

Focus Group Topics

Experiences of lifeguarding: positive and negative
– Hardest aspects of the job
– Dealing with the difficulties associated with the role
– Do these opinions change as lifeguards gain more experience?

Experiences of lifeguarding using technology
– What are the thoughts of those who have used cameras or full DDS?
– Do these technologies help or hinder lifeguarding?
– What is the 'false alarm' rate?
– How does monitoring and interacting with technology fit into normal routines?

How to mitigate difficulties identified in survey: could DDS help with this?
– How do environmental features of pools influence lifeguarding e.g. glare, reflection?
– 'Blind spots': how are these dealt with?
– Pool markings– impact of darker / lighter tiles
– Maintaining concentration and focus

Pool scanning protocols
– How is the 10:20 scanning system viewed?
– Has any allowance for incorporating screen monitoring into 10:20 been made?
– What alternative systems could be used?

Focus Group Outcomes

Following the focus groups, the transcripts were analysed and key themes have been drawn out. The areas below summarise the discussions that were had in the groups.

Maintaining concentration on the job can be hard

>> Poolside environments are often sub-optimal for staying focused and alert. Problems include high temperatures and long working hours, often with short breaks between shifts.

>> Switching positions around the pool helps mitigate some of these issues, with the change in view and zone responsibilty providing a relief from the high concentration levels required.

Factors that increase the difficulty of the job

>> Glare from sunlight and turbulence in the pool caused by other swimmers can cause visibility through the water to decline.

>> Having to deal with other tasks and jobs is distracting and takes attention away from what is happening in the pool.

Experience of using DDS

>> Generally favourable experiences of using underwater cameras and DDS, with lifeguards feeling these provided extra back up and security in case they missed something.

>> Concern over the number of false alarms that occur during normal operation, which is distracting and also reduces trust and confidence in the system.

How are screens used with the scanning protocol?

>> No guidance for how screens should be incorporated within the 10:20 lifeguarding procedure.

>> Sometimes screens have been used as an 'additional check' after the standard 10 second scan. A split 5:5 scan has also been used at times.

>> In reality it is impossible to look at eight screens with ten seconds.

Other ways to make swimming safer (not using technology)

>> Have minimum standards in place to be able to use full size pools and test this ahead of the sessions starting.

>> Have additional procedures in place for those swimmers who require additional support.

>> Have additional procedures in place for the pool when being used for inflatables.

Scanning techniques

>> 10:20 is a useful guideline for scanning but sometimes this needs to be adapted to the specific circumstances of individual pools and lifeguard teams.

>> 10 seconds can be too short to scan the whole pool, but 20 seconds was deemed about right to reach an incident.

10. OPERATOR ENGAGEMENT

Throughout the course of this project we have maintained regular and ongoing engagement with our operator network, gathering and learning from their thoughts and experience in this area. As part of this process, regular updates were given, and feedback gathering sessions were held within existing ukactive forums, namely the CEO forum and the Standards and Legislation Committee. These sessions offered the opportunity to provide key updates but also to ask questions and collect information from the operator representatives. There were also operator representatives in the main stakeholder group.

The idea behind speaking to operators was to understand what the current barriers and facilitators are to installing DDS in their facilities, and what their experiences have been like with using the systems in their pools.

Why did you install DDS at your pools?

1. To improve visibility
There was an opinion that installing DDS improved the visibility of the entire pool, including blind spots such as in the corners of pools.

2. To increase lifeguarding standards
Operators felt that having DDS would improve the standard of lifeguarding at their pools, and even if the technology did not work all the time it was better to have some back up than none at all.

3. To provide retrospective feedback on incidents
Footage from cameras would be useful to review incidents that had happened in the pool retrospectively, both to establish if the correct course of action had been followed but also for training purposes.

Why have you not installed DDS at your pools?

1. Cost
This was by far the most emphasised point, with the most severe barrier to installation being the high costs of DDS. This was particularly pertinent for smaller and public sector operators who simply are not in a position to be able to afford these systems.

2. False alarms
There was particular concern over the number of false alarms being triggered by the system, both from operators who already had DDS installed and those who did not have them.

What is the feedback from use, both from an operational perspective and from lifeguards?

1. No guidance on how to use with 10:20
Lifeguards are expected to use the 10:20 procedure, but no guidance is available on how technology should be incorporated into this. Different pools are using different procedures for lifeguarding using DDS and incorporating screen views into the '10' element of 10:20.

2. Water quality
Installing DDS has had the positive side effect of improving water quality in some pools, as the systems were unable to perform optimally when first installed due to lower water quality, leading to improvements in this area.

11. OVERALL SUMMARY

LITERATURE REVIEW

A full summary of the literature review is included in section 1. The review covered five key topics:

>> Definition of DDS

>> Safety requirements and testing standards

>> Division of responsibility for operating DDS

>> Co-existence with lifeguarding

>> DDS impact so far

LANDSCAPE MAPPING

The purpose of the summary was to provide an overview of DDS currently available on the global market, and to help the sport and leisure industry become more acquainted with the different types, the qualities and characteristics of each, and how they work.

Type 1 – Surveillance, Detection and Alarm Raising
Systems explored: SwimEye AS, Poseidon, AngelEye, Poolview Plus, Coral Manta, diWatch

Type 2 – Detection and Alarm Raising
Systems explored: iSwimband, Wave, SenTAG, BlueFox ST1, SEAL Swimsafe

Type 3 – Surveillance
Systems explored: Zwembadcamera, Poolview, AngelEye view

TESTING

>> Test results across the non-live standard and enhanced test were similar, with 84% and 85% of all detections within 30 seconds respectively and 46% and 48% within the 2 second threshold of the set-off time.

>> Generally, systems detected 'too quick' e.g. before the 2 second threshold had started.

>> Live testing was feasible to carry out and saw a decrease in performance across both standard and enhanced tests, with 82% and 66% detections within 30 seconds respectively, a much bigger drop for the enhanced test.

>> There was no noticeable patterns in the difference in performance between the four dummy conditions (combinations of light and dark skin tones and clothing), with different detection results across the live and non-live versions of the tests.

>> There was a noticeable performance decline in corners and on pool slopes.

LIFEGUARD ENGAGEMENT

>> Of the factors included in the survey, those that most lifeguards said made their job harder were reflection, glare and busy pools.

>> Reaction towards DDS was generally positive– those who used it felt it was a good additional back up and could help with blind spots.

>> There was concern over the number of false alarms (both from those who had used it and those who had not) and the potential that it could encourage complacency.

>> Lifeguards from different pools had a range of experiences with using technology and screens in relation to the 10:20 guideline, with no clear or standardised way to incorporate screen scanning.

OPERATOR ENGAGEMENT

>> There are two main barriers to installation of DDS for operators:

- Cost
- False alarms

>> Those operators that have DDS systems installed them for two primary reasons:

- To improve visibility across the entire pool
- To increase the quality and standard of lifeguarding

>> Feedback around the use of the system was mainly around the lack of awareness or guidance of how to incorporate the use of DDS into the 10:20 scanning routine.

12. REPORT RECOMMENDATIONS AND NEXT STEPS

1. ukactive to lead on communication with ISO, sharing relevant results from the project to investigate:

- **a) the use of 2 second threshold in standard and why 2 seconds is used**
- **b) the use of a smaller dummy with more lifelike features in testing**
- **c) the importance of live testing as part of standard**
- **d) key results from other areas of the project including lifeguard engagement**

The aim of this is to share the relevant findings from our research with ISO, to provide evidence of real life application of the testing procedure and to enable discussion on the specific parts of the standard that have emerged as areas that require further attention.

a) According to the application of ISO:20380, the combined results from the four systems tested did not reach the required standard of 80% of detections within 2 seconds of the set off time. When testing, the early detection of alarms was a primary reason for not reaching this threshold. Systems were frequently detecting the dummy ahead of the 2 second window, which would be classed as a non detection according to the standard, but for example in a real life scenario could mean an incident was detected in 7.5 seconds rather than 8 seconds, which is a positive outcome.

Further complexity is added to the test as it relies on human vision and judgement to determine exactly when the dummy is stationary on the bottom of the pool and timing should begin. Given these factors, we intend to share our findings with ISO and understand what the research base behind using a 2 second threshold is, and how this was determined. A potential suggestion could be extending the allowance ***below*** the set off threshold so systems that detect quickly are not penalised for this, whilst still maintaining the 2 second tolerance above the threshold. In this scenario a balance between quick detections and false alarms would need to be considered.

b) The enhanced test saw a similar detection performance to the standard test in non-live conditions, leading to the suggestion that the smaller dummy with more lifelike features could be adopted for regular testing without a performance decline. The enhanced test achieved a lower detection rate than the standard test under live conditions, suggesting that if live testing is to be carried out (as recommended below), the smaller dummy with more lifelike features would be a better model to use as it offers a more rigorous test and is more applicable to real life scenarios. The test results indicated that the skin tone and swim wear colour did not lead to a noticeable *pattern* in the difference on detection performance (there were different detection results across the live and non-live versions of the tests) so the focus here should be on the size and design of the dummy rather than skin tone or swim wear colour.

c) The difference in performance between live and non-live conditions for the enhanced standard highlights the need for pools to be doing some element of live testing. The implementation of a full live test, as was carried out in this project, would not be practical for a regular test but could be carried out as an additional test when the standard six monthly full tests are carried out. In addition to this, and linked to recommendation number 2 below, is the need for pools to carry out some form of live testing as part of normal regular testing of the system (over and above any tests required by the ISO standard). Pools should already be carrying out daily testing of the system, and introducing a live test of some areas of the pool whilst the pool is quiet could be incorporated into this.

2. ukactive to create working group with relevant parties to work towards creating an industry guideline for testing and using DDS. This will include procedures for testing, including live testing, and a review of 10:20 and using technology as part of lifeguarding.

Whilst it is important to share our findings with ISO, the nature of an international standard means that multiple countries are involved in setting and reviewing these, and some degree of compromise across multiple stakeholders is always required. Therefore rather than attempt to change the ISO standard, *we will instead focus on bringing together the right stakeholders from across the sector to produce an national industry standard for the use of DDS, including the testing of these and how they should work in conjunction with lifeguards. Ultimately this should lead to the creation of industry standards, which can be applied alongside ISO_20380.*

As part of a move towards creating industry guidelines, there are three key areas from the project that this working group will seek to address:

1. Live Testing
The importance of live testing and the lack of current protocol around this is a topic that the group would seek to address through producing guidance on how to carry out live testing under operational conditions. This would be based upon learnings from the live testing elements of the project.

2. Awareness of importance and requirements for testing systems
Experience from carrying out tests at various pools, and attempting to collect previously recorded test results, suggest that there is little awareness of current DDS testing requirements across the sector. The ISO_20380 test is time consuming and requires significant set up and preparation time. Whilst it is not in itself difficult to carry out, it requires a high level of concentration and focus to ensure it is correctly implemented. New industry guidance would seek to ensure that testing is carried out regularly by creating tests that can be easily carried out by operators.

3. DDS and the 10:20 guideline
Feedback from lifeguards and operators highlighted the current inconsistencies with how DDS were being used within standard lifeguarding procedures, particularly with reference to 10:20. Pools are using their own adaptations of this guideline to incorporate checking the screens for incidents and alerts, with a variety of different adaptations including splitting the '10' segment further into 5:5 and using the screens as an 'additional' check at the end of the scan. This is an area where further support and guidance would be useful to ensure the most efficient, and safest, methods of scanning are being used where technology has been introduced to a pool. For this to happen, there needs to be agreement amongst the subject experts on the best way to proceed amongst. Industry guidance would seek to produce a standardised method for using DDS alongside lifeguarding guidelines.

3. ukactive to write to manufacturers, summarising results from testing and highlighting the negative impact of false alarms on lifeguards.

The aim of this is to make manufacturers aware that lifeguards find the number of false alarms distracting, with a view to improving the technology to reduce the frequency.

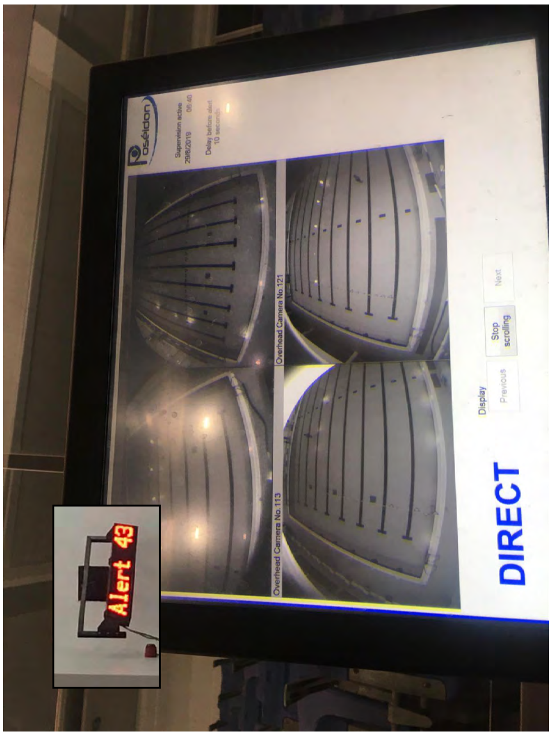
Feedback from users was that the false alarms from the systems were distracting and left lifeguards lacking trust in the system. A small number of false alarm incidents were witnessed during the testing of the pools. This is an area where manufacturers should work to improve the technology to reduce the frequency of false alarms. This was key feedback from the operators when exploring the barriers to installing DDS and operational issues surrounding its use. The letter to the manufacturers will also summarise the testing results with particular reference to the areas where detection performance was seen to decline e.g. corners of the pool.

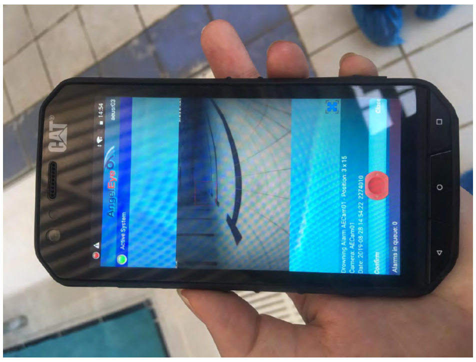
4. ukactive to create project summary for publishing, with top level findings and next steps.

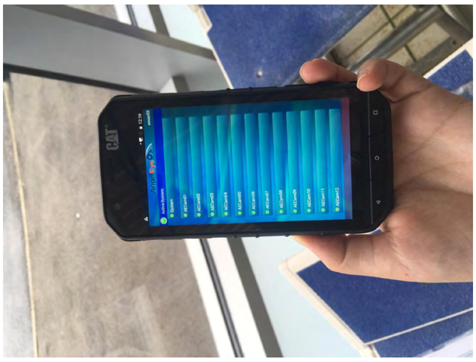
The aim of this is to produce a clear and concise document summarising the entire project and detailing what will happen next.

We will produce a summary version of this report which will be more suitable for parties who have not had prior involvement in the project.

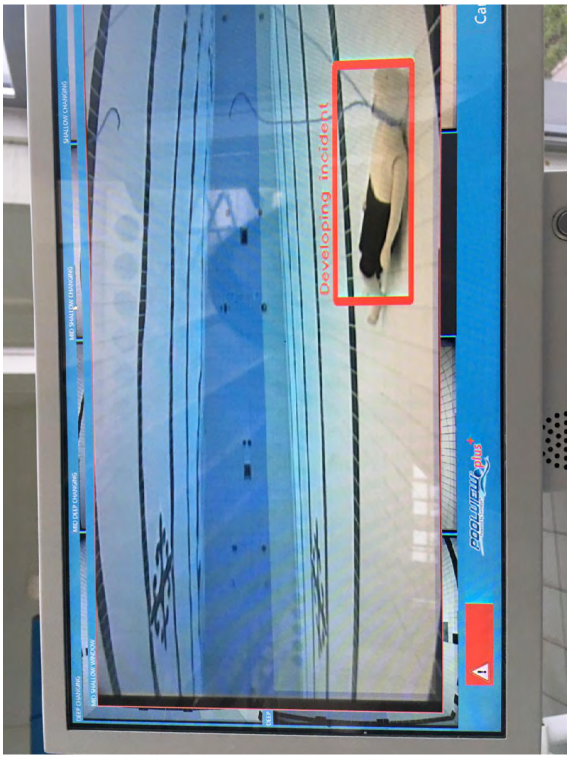
DDS system interface

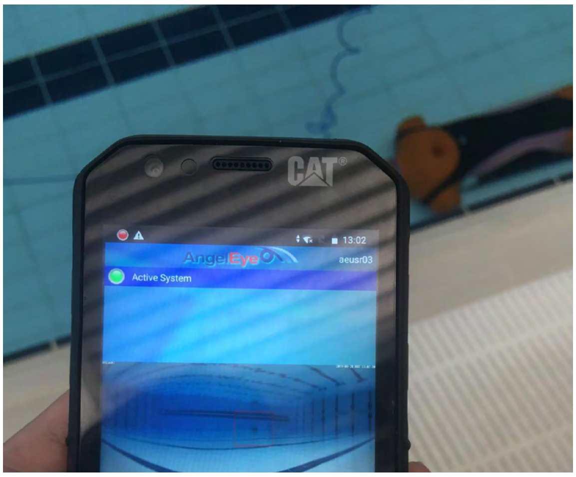


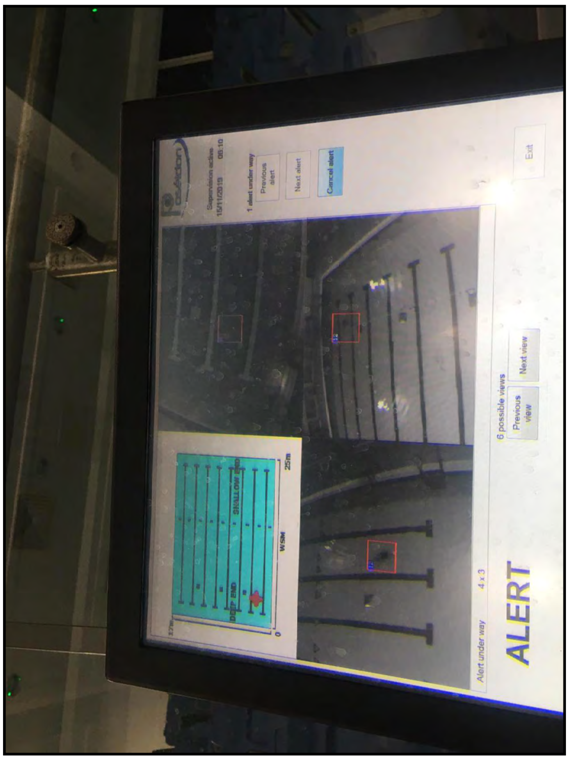


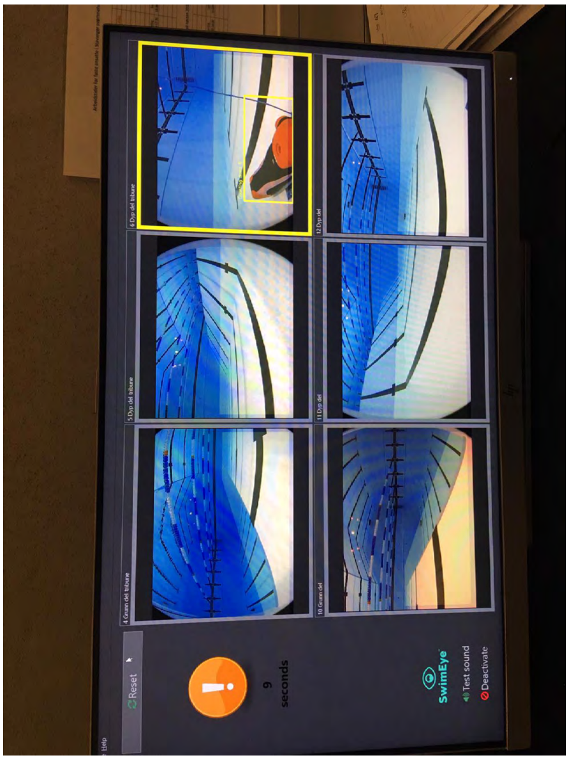


DDS system alerting to incident

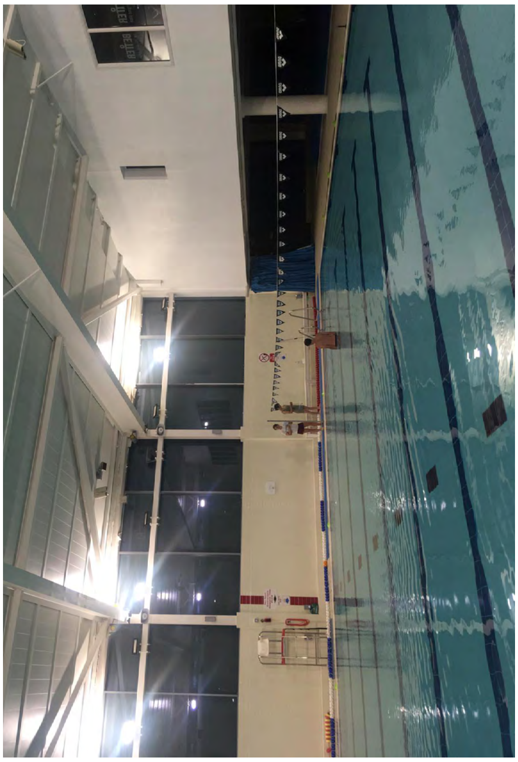




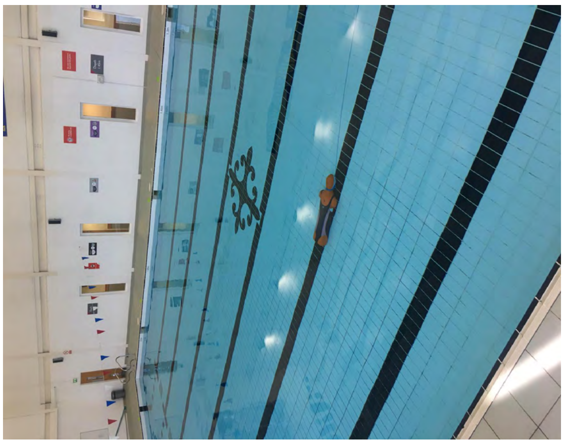


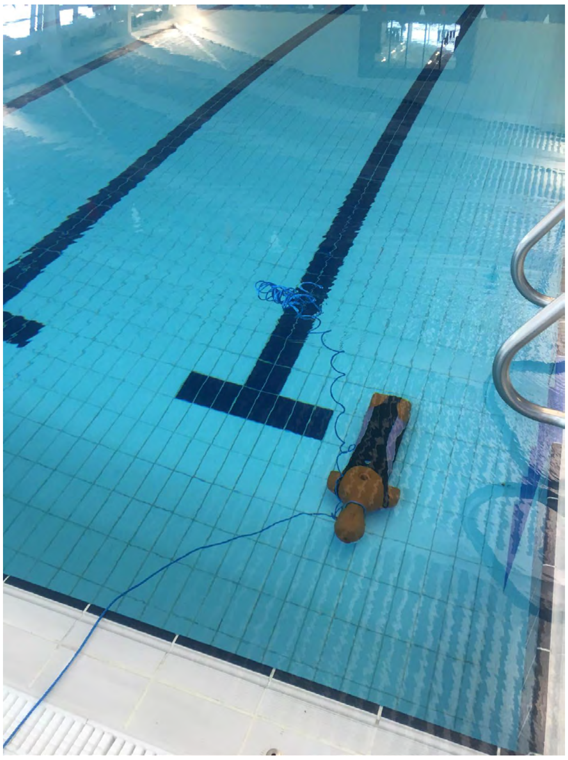


Testing procedure: Standard

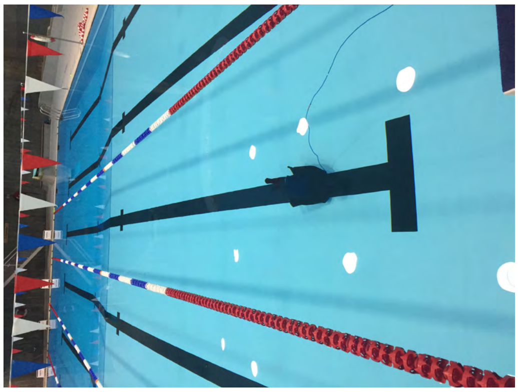


Carrying out a non detection test





Test procedure: Enhanced



Testing on the pool markings

Complete Testing Methods

ISO Standard test

1. Using a tape measure, the number of testing lanes across the width of the pool were marked out using cones, and the same repeated across the pool length to clearly mark out the test areas for the detection test. Between the differing pool sizes, this resulted in 42-54 test areas per pool.
2. Using alternative coloured cones from step 1, the test area for the non-detection test was marked out in the shallow end (<1.5m) of the pool to mark out the 5 non-detection test positions.
3. A light reading was taken and recorded at all four corners of the pool using a lux meter.
4. The test start time and pool orientation was recorded into the testing document.
5. Next the non-detection test was carried out. An assistant stood stationary in each of the 5 test positions in the empty pool for 40 seconds, timed using a stopwatch. If the alarm was activated by the stationary swimmer within the 40 seconds, this was recorded as a fail. If the alarm did not react for the 40 second duration, this was recorded as a pass.
6. During the non-detection test, the system was observed to check whether the system's reaction was due to the assistant in the pool rather than a false alarm detection, such as detecting darker pool tiles.
7. The standard orange lifeguard training dummy was used and prepared by dressing it in a woman's dark coloured swimming costume and tying a rope with measured markings around its neck to help guide the dummy into each test position.
8. Next the detection test was carried out. The dummy was placed in the first test area of the test lane in the empty pool and submerged.
9. Once the dummy was laid stationary on the pool floor, a stopwatch was used to time and record the number of seconds until the alarm reacted.
10. The system monitor was observed to ensure the alarm was triggered by the dummy rather than a false alarm reaction and if reactive, the alarm then dismissed. If the system did not react within 30 seconds, this was recorded as a non-detection within this time.
11. Other observations such as whether the dummy rested on the darker tiles of the pool floor were also recorded. To calculate a fair number of tests to be conducted on dark pool floor tiles, the proportion of dark tiles on the pool floor were calculated as a percentage of the total pool floor surface area, and 10% of this was used to determine the number of dark tile tests to conduct.
12. Once the alarm was dismissed or a non-detection recorded, the rope was pulled from the opposite end of the lane, pulling the dummy into the next test area and the procedure repeated until all test areas of the pool were tested and recorded.
13. Next, the dummy was placed in each corner of the pool and the procedure repeated to record the system's performance in each corner.
14. Testing was also carried out to identify whether the system was able to detect simultaneous incidents. This was done by submerging two standard dummies in different areas of the pool at the same time.
15. The test finish time was recorded into the document.

ISO Standard Live test

1. For the live test a smaller number of test positions were measured out using tape measure and cones. 4 lanes across the width and 6 lanes across the length of the pool were marked out to identify 24 live test areas.
2. For the live conditions non-detection test, the same test area was used in the previous non-detection test in empty pool conditions.
3. The non-detection test was then carried out, with 10 or more members of the public carrying out routine swimming activity. The assistant stood stationary in the 5 test positions of the pool and the stopwatch was used to time the 40 second duration to observe whether the system was able to detect the assistant.
4. The system was observed to ensure that if the alarm was triggered in the non-detection test, it was due to the assistant standing stationary rather than other activity in the pool.
5. Next the detection test in live conditions was carried out. After removing the rope, the assistant in the pool submerged the dummy into the first test area and when stationary, the stopwatch used to time and record the results.
6. The system was monitored to ensure the alarm was triggered by the dummy rather than by false alarm

activity. Other observations such as whether the dummy rested on the darker tiles of the pool floor were also recorded.
7. After the alarm was dismissed and a time or non-detection recorded, this process was repeated until all 24 areas of the pool were tested, whilst swimmers continued their swimming activity throughout.
8. The corners were then tested following the same procedure.
9. Lastly the test finish time was recorded into the document.

Enhanced test

1. For the enhanced test, the cones and tape measure were used to mark out 12 equal test areas of the pool. This consisted of 4 test areas across each of 3 pool lanes.
2. Using the lux meter, light readings were taken and recorded at each of the pool's 4 corners.
3. The light skin-toned, child-sized dummy used for the enhanced test was prepared by dressing it in children's dark coloured swimming shorts leaving the rest of the dummy's light skin tone exposed, and a rope tied around the neck.
4. The test start time and pool orientation was recorded in the test document.
5. Next the dummy was submerged into the first test area of the empty pool and from the point of the dummy laying stationary, the time until the alarm was set off or a non-detection was recorded with the stopwatch.
6. The monitor was observed each time by a assistant to ensure the system was triggered by the dummy rather than by a false alarm trigger.
7. Other observations such as whether the dummy rested on the darker tiles of the pool floor were also recorded. To calculate a fair number of tests to be conducted on dark pool floor tiles, the proportion of dark tiles on the pool floor were calculated as a percentage of the total pool floor surface area, and 10% of this was used to determine the number of dark tile tests to conduct.
8. After the alarm was dismissed and a time or non-detection recorded, the dummy was pulled with the rope from the opposite end of the pool lane into the next test position. The detection test was repeated until all 16 areas of the pool (including the corners) were tested.
9. Next the dummy was removed from the pool and the light coloured swimming shorts were put on the dummy, and detection test procedure repeated.
10. To test the systems performance on darker skin tones, the dummy was prepared by dressing it in brown tights and a brown long-sleeved top to cover the dummy's surface area to imitate a darker skin tone. The dark coloured shorts were used, and the test procedure repeated. The same was carried out again with the light coloured shorts to ensure all four skin tone and swim wear colour combinations were tested.
11. Lastly the test finish time was recorded into the document.

Enhanced Live test

1. 6 test areas of equal size were marked out using the tape measure and cones along the pool edge. This consisted of 3 test areas across each of the 2 testing lanes.
2. The light skin-toned child-sized dummy was dressed in children's dark coloured swim shorts and the rope removed from the neck.
3. The assistant submerged the dummy in the first test area of the pool.
4. The detection test was then carried out in live conditions, with 10 or more members of the public engaging in routine swimming activity, and the systems reaction time measured and recorded with the stopwatch.
5. The monitor was observed each time by a assistant to ensure the system was triggered by the dummy rather than a false alarm, and other observations such as whether the dummy rested on darker pool tiles was recorded.
6. After each of the 6 test areas were tested, the dummy was changed into the light coloured shorts and the test repeated whilst the swimmers continued their swimming activity throughout.
7. To imitate darker skin tones, the dummy was dressed in brown tights and a brown top covering the full surface area of the dummy. The test across all 6 test areas was carried out and repeated for both dark and light coloured swim shorts.
8. Lastly the test finish time was recorded into the document.

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