Background Chapter, Literature Review, and Approaches

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1 Background

1.1 Royal National Lifeboat Institution

The Royal National Lifeboat Institution - RNLI - is a charity which save lives at sea. It is based in UK, Republic of Ireland, and the Channel Islands. In 2016, their crews and lifeguards saved 558 lives, with 8,851 emergency launches. Operating 238 lifeboat stations, and patrolling 240 beaches cost the institution £168.1M in 2015[1]. The cost of training a single lifeguard is £673, with the cost of a lifeboat crew member being considerably higher. [2]

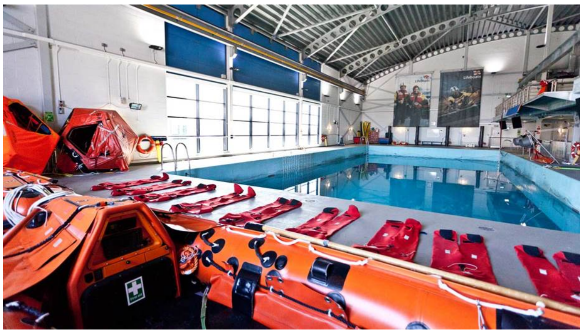

Figure 1: Training facility where crew members train lifesaving skills

1.2 RNLI Training

The RNLI recruits and trains volunteers in order to save lives at sea. By the voluntary nature of recruits, it is not - and can not - be a requirement that a person has maritime experience prior to recruitment. Thus, the RNLI has a robust structure for crew development. Training consists of both theoretical training in a classroom, and sea-based, practical training.

The current format of training at the RNLI is that each crew member follows a structured training programme. This programme consists of multiple competence based training units, which cover an agreed range of skills required to complete a task. [3]. Each unit consists of a classroom theory element, and a practical element.

To bridge this divide between theory and practice, all crew must attend a 1-week training course at the RNLI College in Poole. During this week, crew receive practical training in a specifically built facility-shown in Figure 1; this training ranges from fire fighting, capsize drills, and sea survival. This process is expensive, but absolutely crucial to the safe functioning of Lifeboat stations. Due to the turnover of voluntary crew members, which increases the average costs of a fully trained crew member, It is not possible to frequently train crew in this manner.

Scenario-based training is similarly difficult to implement, because of the hazardous nature and potentially high cost of the scenarios for which a crew member must trained. Most notable of which is capsize training, an actual situation where a vessel capsizes will almost always be in terrible weather conditions, and sea state. But, unfortunately, the only way in which to replicate this in practice is by artificially capsizing a specifically designed vessel in a large pool or safe waters. Thus, an alternate method for which to replicate these situations would be invaluable not only the RNLI, but to all organisations which require training which is impractically hazardous or costly to conduct effectively.

1.3 Technological Progress

The persistent march of technological innovation and progress present opportunities in every industry, this is similarly true for practical training. Digitally simulated training environments are widely used, with the military and commercial aviation industries being the biggest investors. Training environments can be recreated in 3D as a simulator, allowing a user to be trained through a digital environment. 3D Simulators are not a new concept, but the creation of complex 3D applications has become considerably more accessible in recent years using free-to-use platforms such as Unity3D and Unreal Engine, and the ever increasing computational power of electrical devices.

[1]RNLI: Where yours money goes `https://goo.gl/UjACQK`
[2]RNLI Annual Reports and Accounts`https://goo.gl/XqhCZn`
[3]RNLI: Lifeboat crew training `https://goo.gl/kuCafE`

Of specific interest in this project is the more recent progress of Virtual Reality - VR - devices. This trend began with the development of the Oculus Rift - which was later purchased by Facebook. As with most innovations, the Oculus Rift is no longer the best selling headset, being replaced by the HTC Vive [4] many other tech giants have released similar devices, such as the Samsung Gear VR, Google Cardboard, Playstation VR. With a fierce competition to capture a large share of a young market, pricing of high quality VR devices are falling year on year. Many VR devices - such as the Cardboard and Gear - take advantage of the power of modern high end smartphones.

Creating 360-degree images and videos is now possible from most mobile devices, this can be done by stitching multiple images of a single scene together, in order to create a full image. Such methods construct a static 2D image, which can be interactively explored by a user. Dedicated cameras are becoming more widely available, utilising mutliple omnidirectional cameras which capture video and automatically . The increased demand for 360-video lead to the largest video viewing platforms, YouTube and Facebook, both launching a feature in 2015 which allowed viewers to watch and interact with such videos [5].

In a similar manner to 360 photography, adoption of VR technologies has been rapidly increasing in recent years. With Facebook acquiring the VR company Oculus in 2014 [6], and Google releasing its own VR interface for smartphones in the same year [7].

With the time and cost requirement of both creating and interacting with 3D Virtual environments decreasing, there exists many opportunities for organisations such as the RNLI to utilise these technologies for training purposes.

1.4 Using Technology in Training

The technological innovations mentioned in section 1.3 are offering new and fascinating ways to bridge the gap between theoretical and practical training. These opportunities have not gone unnoticed by organisations such as the US, Canadian, and Royal Navy. Each conducting research in the early 21st century into ways in which virtual environments could be implemented most effectively. The typical approach to a training system is to construct a 3D model of the vessel that the user can move through, and interact with.

A computer generated - CG, virtual reality - VR, implementation of this seems like the natural progression of this, allowing a user to have a greater sense of presence. But, the recent development of 360 imaging presents a new opportunity to create a virtual training system, with far less software development expertise required. A simple application of 360 imaging for training could be that a trainee simply watched a 360 video through a VR headset, allowing user to acquire a level of spatial awareness from a digital experience.

The two available approaches - VR and 360-video - offer clear virtual benefits: VR allows a user to interact and manipulate a scene, and is dynamic; 360-video offers a photo-realistic representation of a scene. But, there are also economic factors which must be considered: VR requires software development expertise, therefore time and funding; 360-video can be created quickly, with relatively cheap equipment. Both require sufficient hardware, i.e. VR headsets, and computer systems or high-end mobile devices. Hardware costs have been rapidly decreasing and can be expected to continue to do so.

1.5 Research Questions

From the above discussion, it is possible to determine the following research questions:
Which technological approach is the most efficient method of training crew members?
What are the causes of any disparity between approaches?
Thus, it is necessary to quantify the functional differences between these two approaches in the training of crew members. To do so, the current understanding of the field of psychology for practical training must be explored.

2 Relevant Literature

2.1 Spatial Cognition

According to Stone et al. (2009), the term spatial awareness can be applied to the immediate environment in which one exists or to a remote environment in which an extension of oneself has been deployed, such as a remotely operated vehicle or manipulator, or a virtual environment.

Of particular importance to the RNLI, is a member of crew's acquisition of knowledge of the relative scale and position of a equipment on a vessel, and of the local geography. The acquisition of spatial awareness is referred to as spatial cognition, and is the foundation which allows a person to perceive, recall, alter, and

[4] HTC Vive Outselling Oculus Rift 2-to-1 `https://goo.gl/SfqrM2`
[5] Facebook joins YouTube in showing 360-degree videos – including Star Wars `https://goo.gl/H9iE6f`
[6] Facebook closes its $2bn Oculus Rift acquisition. What next? `https://goo.gl/UQSTsP`
[7] Google Cardboard launches in UK for £15 `https://goo.gl/f9CS8f`

communicate spatial information.

Osberg (1993) states that it is easy to assume that spatial cognition is a visual process, whereas it is in fact a multifaceted, multi-perceptual sequence of events. The quality of distinctiveness or memorableness is not solely the result of the way the environment looks (Downs & Stea 1973). Although this is not a profound statement, it is important to consider, since the most intuitive view may be that the most accurate representation of an environment would be the most effective method for training. Given a scenario where only visual information is available, it would still not be necessarily true that the most accurate representation would be the most effective for training purposes. Gleick (1987) gives an interesting perspective, an artist's most powerful trait is realising that only a small amount of things are important, and they are able to see what they are. For direct sources of information, the visual, tactile, olfactory, and kinesthetic sense modalities combine to provide an integrated representation of the spatial environment (Downs & Stea 1973)

The widely accepted hierarchy for the development of spatial awareness is the landmark-route-survey hierarchy, first proposed by Siegel & White (1975). Landmark knowledge relates to the presence of dominant object, or groups of object. Route knowledge is the development of a familiarity of paths between landmarks. An survey knowledge is the integration of both landmark and route knowledge. Using these three sets knowledge, an accurate representation of an environment can be compiled (Stone et al. 2009).

2.2 Spatial Cognition in Training

The ultimate goal of training is to have an individual who is able to perform a desired task, and as said by S Hussain et al. (2009), execute the necessary skills, quickly and without hesitation. This is absolutely crucial in the instance of the RNLI, since the trained tasks may be performed under high stress, in life-threatening scenarios. Training is most robust when it is habitual or automatic (S Hussain et al. 2009). This can be made possible by forcing trainees to over-learn a task, such that it requires minimal cognitive processing (Kirlik et al. 1998).

2.3 Training in the Virtual Environment

Osberg (1993) identifies that a virtual environment - VE - offers a range of attributes which make it extremely well suited to training. Crucially, VEs offer an infinite amount of flexibility in the recreation of environments, This is trait which has been utilised since the original conception of VE-based training, and remains its most powerful.

Secondly, virtual environments allow a user to feel a sense of presence (Osberg 1993). Presence is the experience of a virtual environment, such that a user feels that they are "there" (Steuer 1992). In fact, the premise of virtual reality is to maximise the experience of presence to the point that a user is not aware that they are in a virtual environment. This accuracy relies on scale, position, and fidelity of objects within that scene; secondly, it relies on the accurate and responsive display of the scene to the user; vividness and interactivity positively relate to the sense of presence (Steuer 1992).

Finally, interactivity is an attribute of virtual environments which may contribute to an improvement of a training system's success. Motor activity has a fundamental role in the acquisition of spatial awareness; interaction with an environment is absolutely necessary for the correct interpretation of that environment (Siegel & White 1975). Osberg (1993) stipulates that the ability to move freely is essential in order for an individual to form a spatial representation of an environment. Interactivity can be considered to be associated with the exploration mode of the user through the VE, either passive or active exploration. Wallet et al. (2009) showed that active exploration may have a beneficial effect on spatial cognition. Although, according to Wallet et al. (2009) studies of these two strategies of exploration offer inconclusive results, and may be a result of varying complexity of tasks. This may be contradictory to training theory according to Goldstein & Ford (2002), who states that any complex task must be broken into smaller tasks which can be individually trained to proficiency before integrating these learnt skills to the entire complex task. Which leads to a dilemma: active exploration may be more effective for complex tasks, but training is generally more effective when complex tasks are divided and conquered as simpler tasks. For further complexity, Waller et al. (1994) found that VEs are more effective than real world training only after extensive exposure to the training environment. As such, the complexity and length of the training exercise will be a crucial factor to be considered when constructing an application and during testing.

2.4 Summary

The topic of spatial cognition is one without concrete conclusions. The way in which spatial information is gathered from some environment, and how it is organised within the brain is not concretely known, as is the way in which that information is recalled. It is evident that it is not simply a visual process, and many other sensory modalities are utilised; of particular importance to this study is the effect of motor activity and visual information.

As discussed, the attributes of a virtual environment which may effect spatial cognition or illustrated in Figure 2.

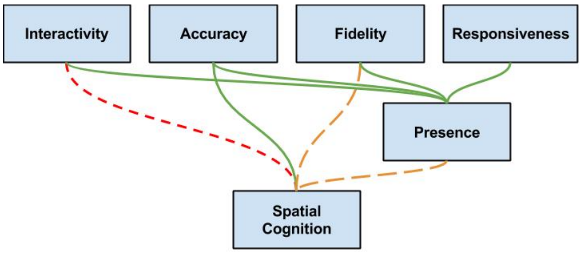

Figure 2: Diagram illustrating the relationship between attributes of a virtual environment and their effect on spatial cognition

The lack of concrete evidence to support the effect of interactivity, fidelity, and presence on spatial cognition, is illustrated. Thus, these attributes are the focal point of this study; the research questions stated in section 1.5 can be refined to:

To what extent do Interactivity, Fidelity, and Presence effect spatial cognition in a Virtual Environment?

3 Approaches

3.1 Technology

Modern technology offers two methods to place trainees in interactive virtual environments, 360-degree imaging, and computer-generated virtual reality; although 360-degree video is often disputed to be a form of VR [8], the two technologies will be referred to as 360 and VR for simplicity.

3.1.1 360 Imaging

The RNLI has experimented with 360-imaging in the past, creating a tour of their new Shannon-class All-weather Lifeboat [9]. This application allows a user to explore a series of 360 images from within the vessel. In this instance, the fidelity of the environment is high, as it is photo realistic; which has been proven to be crucial for training. This application also offers some level of interactivity, which may be moderately effective in the training of crew members. Although, according to previous studies interactivity, and active exploration may be essential to effective training. Finally, since this application only uses static images, it is very difficult to give the user a sense of presence, which may be important in the performance of users within the VE - as studied by Coxon et al. (2016).

In order to improve the flexibility of the application, as well as the interactivity, a 360-video application may be the most effective approach to take.

3.1.2 Computer Generated Virtual Reality

The expansive list of available platforms to recreate an environment. The goal of this application is to reduce the number of factors which may lead to a disparity between the 360 and CG versions. Thus, at a minimum the scale, and position of objects within each scene should be close to identical. Maximising the amount of interactivity within the CG environment is a priority, to ensure that the disparity of interactivity between each medium is maximised. Modern game development platforms offer extremely powerful tools to facilitate the construction of immersive, and interactive virtual environments. Specifically, Unity3D and Maya will be used to construct these virtual environments.

3.1.3 Viewing Hardware

To maintain consistency, and reduce variables between each application, it will be important that both applications feel identical to the user - excluding interactivity and fidelity. To achieve this, both applications will utilise the same viewing hardware. Notably, in practice, viewing a computer-generated VE environment requires far more sophisticated hardware, and is thus more complex and expensive to use.

3.2 Testing

In the interest of maximising statistical power of a potentially small sample, a counterbalanced within-subject study will be conducted.

3.2.1 Complexity

It is clear that the spatial cognition of a user in the VE is effected by the complexity of the task. A testing scenario of varying complexity and length must be utilised in order to ensure a robust study. Thus, the first requirement of the study is that it should consist o multiple stages ranging from simple to complex.

[8]STOP CALLING GOOGLE CARDBOARD'S 360-DEGREE VIDEOS VR `https://goo.gl/UGthLf`
[9]RNLI VR Tour, for Cardboard `https://goo.gl/1Ha6vs`

As described in section 1.2, crew members at the RNLI complete a series of competence based units as part of their training. Within the RNLI, one of the first and most trivial training units a recruit completes is *Boat Layout*. Knowledge of the location of a long list of equipment on a vessel is crucial; and the ability to immediately recall this information is invaluable. This test is the basis of the most trivial task a user completes during this study.

Later units crew members must complete is patch knowledge, this unit is part of the *Helmsman*[10] plan. Patch knowledge is a helmsman's knowledge of the area in which they are required to cover; this requires the helmsman to have a well trained spatial knowledge of beaches, rocks, cliffs, caves etc. within that are. This is a crucial skill for any helmsman, in order for the Lifeboat to be able to attend any scene in a safe and prompt manner. Therefore, this unit is the basis of the second, more complex task a user completes during this study.

4 Application Design

4.1 Boat Layout

The application trains the user to have spatial awareness aboard the D-Class Inshore Lifeboat shown in Figure 3. The D-Class has a total of 9 compartments, a *pod*, and a 40HP outboard engine. Each compartment consists of various emergency equipment; such as, towlines, first aid kits, survivor's Life jacket etc. The *pod* is the housing for the navigational and communications equipment. In order for a crew member to successfully pass the *boat layout* unit, they must be able to recall each item and its use; i.e. they must have acquired a sufficient level of landmark knowledge aboard the vessel.

Figure 3: Image of the D-Class Lifeboat at sea.

The application allows a user to experience being a board the D-Class. In the 360 environment, the user is able to explore actual footage aboard the D-Class, and on the command of the user, each compartment is opened and the contents are shown to the user. In the VR environment, the user is able to actively explore the vessel at their own will. Opening compartment as they please, and interacting with objects within each compartment.

4.2 Patch Knowledge

Testing patch knowledge requires the user to travel around a small geographical area, New Quay Harbour - shown in Figure 4. This area consists of multiple landmarks and hazards, such as piers, beaches, boats, and rocks. The user must remember these landmarks, and be able to travel between them, utilising their landmark, route, and survey knowledge acquired of the area.

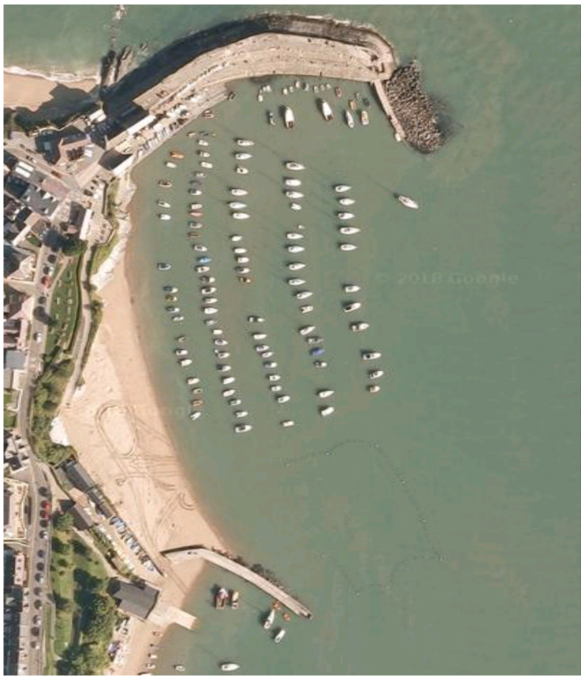

Figure 4: New Quay Harbour, West Wales

[10]A helmsman on an ILB is the most senior member of crew, and is responsible for steering the vessel.

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