Serious Games For Defence Training: Using The Location And Scenario Training System To Enhance The Spatial Awareness Of Trainee Submariners.

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Abstract. Rapid advancements in computer technology have facilitated the development of three dimensional (3D) computer-generated simulation environments that have been utilized for training in a number of different fields. In particular, this development has been heavily influenced by innovations within the gaming industry, where First Person Shooter (FPS) games are often considered to be on the cutting edge of gaming technology. 3D simulation environments built upon FPS gaming technologies can be used to realistically represent real world places, while also providing a dynamic and responsive experiential based learning environment for trainees.

This paper reports on a study to explore the effectiveness of 3D simulation environments based on FPS gaming technologies to enhance the spatial awareness of trainee submariners in unfamiliar real world spaces. The Location and Scenario Training System (LASTS), developed by the Royal Australian Navy, was evaluated to determine whether experience within the LASTS environment could benefit trainee submariners on Collins class submarines. The LASTS environment utilises the Unreal Runtime FPS game engine to provide a realistic representation of the Main Generator Room (MGR) on-board a Collins class submarine. This simulation was used to engage trainee submariners in a simplified version of the 12 Point Safety Round (12 PSR) exercise performed inside the MGR.

Five trainee submariners were exposed to LASTS and then required to conduct the simplified 12 PSR on-board a Collins class submarine. This mode of learning was compared to traditional non-immersive classroom teaching involving five additional trainee submariners who were also required to complete the same exercise inside the MGR.

Results indicated that LASTS trainees performed the simplified 12 PSR more effectively than non LASTS trainees. There was also some evidence to suggest that the LASTS trainees possessed a better overall spatial representation of the MGR compared to those who received traditional classroom based training.

1. INTRODUCTION

Computer-generated simulation environments are well recognized as learning and training tools due to their ability to represent any real or imaginary process, entity, or environment, including it's underlying behavioural characteristics. Three dimensional (3D) computer environments are particularly well suited in this capacity as the three dimensional perspective they offer allows them to potentially represent real world spaces realistically and more intuitively than other forms of media. 3D simulation environments can thus be used to provide learners with a degree of comparable experience before subjecting them to the real world environment that is being represented.

3D simulation environments allow users to experience environments that may be of impractical size, infeasible distance, prohibitive cost, or too significant a hazard to visit in person (Baylis, 2000). The real world environments being represented may also be difficult to set up for instruction, difficult to observe in operation, or may have limited suitable available time, potentially making training prohibitive (Towne, 1995). These issues are of particular relevance to organizations such as the Royal Australian Navy, who are somewhat limited in their ability to provide training on-board Collins class submarines as they are often deployed or undergoing maintenance. This training is essential in order to provide trainee submariners with the required knowledge to traverse a Collins class submarine efficiently, safely and effectively, whilst retaining locational awareness of specific areas and objects within the environment.

As such, there is an inherent need to provide trainee submariners with some understanding as to the spatial characteristics of a Collins class submarine, despite the fact that real world training experience within this
environment is often not available due to deployment or logistical considerations. It would seem that 3D simulation environments have the potential to recreate these types of environments realistically, such that spatial knowledge obtained within the simulation can be transferred to the real world environment being represented. In this fashion, trainees can develop a degree of spatial awareness of the real world environment without actually engaging with it, providing that the simulation environment provides a meaningful and accurate representation.

2. SPATIAL LEARNING WITH A 3D SIMULATION ENVIRONMENT

A model identifying the contributing factors to spatial learning within a 3D simulation environment based on FPS gaming technology was developed to provide a foundation from which to evaluate the effectiveness of the LASTS environment as a tool for spatial learning. This model was in turn used to develop a series of evaluation criteria which were used to determine the effectiveness of each of the identified contributing factors within the LASTS environment. Thus, the LASTS environment was evaluated in terms of its ability to enhance the spatial awareness of the MGR for trainee submariners in accordance with these criteria.

![Spatial Cognition](image)

**Figure 1**: A model detailing the contributing factors to spatial learning within a 3D FPS simulation environment.

The model and subsequent evaluation criteria were derived from a thorough examination of literature relevant to this field of study. This review entailed an exploration as to the nature and function of spatial cognition, learning transfer between simulation and real world environments, and the characteristics of 3D environments based on gaming technology that facilitate the representation of real world spaces.

2.1 Spatial Cognition

The process of spatial cognition entails the acquisition and development of cognitive maps, an on-going and iterative process comprising of “a series of psychological transformations by which an individual acquires, codes, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment” (Downs & Stea, 1973, p. 9). The spatial information used in the construction of cognitive maps can be acquired from a variety of sources, such that cognitive maps tend to be abstract mental representations of real world environments that can exist in a multitude of different forms (Downs & Stea, 1973).

While the structure and formation of cognitive maps is debated amongst scholars, it is commonly accepted that the ability to move between points or landmarks in an environment is necessary in order to facilitate the process of spatial cognition (Devlin, 2001; Siegel & White, 1975). The ability to form cogent spatial representations of environments is also dependent on the legibility, or clarity, of an environment, which Lynch (1960) defines in terms of the ease with which the elements of a system can be recognized and organized into a coherent pattern. The need for a visually recognizable and legible representation is supported by research by Peruch, Belingard, and Thinus-Blanc (2001) who argue that it is the quality, not quantity, of available virtual information that is more important in the construction of spatial representations.

2.2 Learning Within Simulation Environments

A simulation exists in order for knowledge learned in the simulation environment to be transferred to the real world system (Towne, 1995). Alexander, Brunye, Sidman, and Weil (2005) measure the success of a simulation based on this degree of knowledge transfer and note that “simulator training is only valuable if skills addressed and improved in the virtual environment are required in the operational environment” (p. 2). Representing the system and it’s underlying behaviour serves to facilitate this objective, with the assumption being that a faithful representation will encourage knowledge transfer between the simulation environment and the real world system.

This assumption is consistent with Brown, Collins, and Duguid's (1989) theory of situated cognition which asserts that knowledge is situated within the activity, context and culture in which it is developed and used. They suggest that activities and situations are integral to cognition and learning, and that learning should be embedded in activity to make deliberate use of the social and physical context of the environment. Thus it can be surmised that learning transfer is most effective between environments that share a common activity, operation or learning goal, and are similarly related in
terms of context and culture.

The idea of learning being dependent on the negotiation of meaning through practice (Dobson et al., 2001) is consistent with the ideas set forth in simulation based learning theory regarding the importance of setting tasks or objectives as part of the learning process. Tait (1994) states that learners generally require support in generating and testing hypotheses which can be achieved via the provision of appropriate learning tasks. Jonassen, Howland, Moore and Marra (2003) argue that it is the nature of these tasks that best determine the nature of the learning the user will complete, and that in order for users to learn meaningfully, they must be willfully engaged in a meaningful task. A number of scholars (Withers, 2005; Van Rosmalen, 1994; Sweller, Van Merrienboer, & Paas, 1998) have argued that these tasks need to be interwoven into the simulation environment itself so as to reduce the demand on working memory and consequently, cognitive load required of the user.

2.3 3D Environments

In order for spatial knowledge acquired within a simulation environment to be transferred effectively, it is necessary for the simulation to provide a perceptible and operable representation of the real world environment it represents whilst also modelling the underlying behavioural model of the system (Di Carlo, 2003; Towne, 1995; Williams, 2003).

3D simulation environments are well suited in this capacity, as they utilize three dimensional Euclidean geometry to describe the objects within them, and as such, can be used to construct scale representations of real world spaces, preserving dimensions, perspective, and relative distances to scale. Furthermore, by utilizing FPS gaming technology, 3D simulation environments can provide users with a high fidelity visual experience, owing to the significant developmental emphasis exhibited by this technology with regard to visual quality (Germannchis, Cartwright and Pettit, 2005). FPS game engines are designed to deliver these high fidelity visuals at a rate consistent with the high performance demands placed upon them by gamers, and as such, are able to maintain the illusion of movement and immediacy of feedback that is provided via an acceptable frame rate (typically greater than twenty frames a second).

Germannchis, Cartwright and Pettit (2005), and Shiratuddin and Thabet (2002) also suggest that the real time movement and control inherent in FPS games allows simulation environments based on this technology to meaningfully represent real world spaces. In this manner, users are able to move and interact freely throughout the virtual environment in a similar fashion to real world environments.

Thus, it can be seen that 3D environments based on FPS game engines are a valid means for simulating real world environments based on their ability to represent three dimensional spaces at a high visual quality while maintaining a frame rate that allows the user fluid control of the virtual environment. The high visual fidelity inherent in environments constructed using FPS game engines has the potential to enhance realism and facilitate a sense of presence and immersion within the virtual environment.

3. METHODOLOGY

The case study examined the LASTS (Location and Scenario Training System) 3D simulation environment developed by the Computer Modelling Group, Navy Platform Systems under the supervision of Training Authority Submarines. The LASTS environment is a non-immersive, desktop environment that utilizes the FPS Unreal Runtime game engine to simulate the Main Generator Room (MGR) of an RAN Collins class submarine. The MGR was the only fully completed room within the LASTS environment available for research.

![Figure 2: MGR compartment of a Collins class submarine as depicted in LASTS.](image)

The twenty-one participants used in the study were selected by Submarine Training and Systems Centre (STSC) from trainee, existing, and ex-submariners within the RAN, as well as training staff from STSC. For the purpose of comparing LASTS to traditional non-immersive learning techniques, participants were formed into two groups (Group B1 and Group B2) of five trainee submariners from the Enhanced Selection Process (ESP) program whose previous experience onboard a Collins class submarine was identified as being limited.

The Chief Petty officer (CPO) was asked to participate in the study in order to evaluate the performance of participants in Group B1 and Group B2 in undertaking a simplified 12 Point Safety Round (12 PSR) exercise onboard HMAS Collins. The simplified 12 PSR was based on the RAN 12 Point Safety Round, a very specific safety process performed on board Collins class submarine.
submarines. This simplified version of the 12 PSR required participants to locate a series of items relevant to the complete RAN 12 PSR within the MGR of HMAS Collins. Their performance was assessed by the CPO in accordance with their ability to recognise items, the degree of confidence they exhibited in locating items, and their general knowledge of the MGR compartment. In addition to evaluating Group B1 and Group B2's performance of the simplified 12 PSR, the CPO was also asked to participate in an interview in order to ascertain his observations during the performance of the exercise.

The simplified 12 PSR enabled a comparison between the spatial awareness of participants in Group B1 and Group B2 as a result of the different types of training each group of participants had received prior to commencing the exercise. Participants in Group B1 were presented with an information booklet containing the names, printed diagrams, and colour photographs of each item included in the simplified 12 PSR, with each item presented on a separate page of the booklet. The printed diagrams consisted of a plan and cross-sectional view of the MGR which denoted the location of the item in question, with the plan diagram depicting the lower or upper deck of the MGR where appropriate. The five participants in Group B1 were told they would be given fifteen minutes to familiarise themselves with the material provided, after which they would be assessed on their ability to locate the items contained in the booklet on-board a Collins class submarine.

Conversely, participants in Group B2 were given a fifteen-minute training session in the LASTS environment to familiarize themselves with the locations of the items included in the simplified 12 PSR. This period included an instructor led walk-through tour of the virtual MGR, during which the locations of these items were pointed out to participants. As with participants in Group B1, participants in Group B2 were also informed that they would be assessed on their ability to locate the items pointed out during the virtual walk-through on-board a Collins class submarine.

4. Results
The simplified 12 PSR exercise involved separate performance evaluations for Group B1 and Group B2, assessing their ability to locate a series of items within the MGR. Both groups of participants had minimal previous exposure to the MGR, with the most experienced of the participants having had two previous walk-through tours of the entire submarine only. The CPO evaluated the performance of each participant on a scale of zero to ten according to their ability to recognise items, their general submarine knowledge, and their confidence in performing the exercise. The scores assigned to each participant for each item are detailed in Table 1, with Figure 3 graphing the average scores for each item for Group B1 and Group B2 respectively:

<table>
<thead>
<tr>
<th></th>
<th>B1_1</th>
<th>B1_2</th>
<th>B1_3</th>
<th>B1_4</th>
<th>B1_5</th>
<th>B2_1</th>
<th>B2_2</th>
<th>B2_3</th>
<th>B2_4</th>
<th>B2_5</th>
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<th>B2 Average</th>
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<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Halon Release Bottle</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>10</td>
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<td>9.4</td>
<td>9.8</td>
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<td>Fire Extinguishers</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td>10</td>
<td>9</td>
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<td>OCCABA Stowage</td>
<td>9</td>
<td>9</td>
<td>10</td>
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<td>10</td>
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<td>10</td>
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<td>9.4</td>
<td>10</td>
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<td>Fire Fighting Hose Reel</td>
<td>7</td>
<td>9</td>
<td>1</td>
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<tr>
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<td>9</td>
<td>9</td>
<td>8</td>
<td>10</td>
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<td>9.2</td>
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<tr>
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<td>8</td>
<td>1</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<td>7.6</td>
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<tr>
<td>AFT Submerged Signal Ejector Controller</td>
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<td>10</td>
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<td>10</td>
<td>10</td>
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<tr>
<td>Average Score</td>
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<td>9.5</td>
<td>8.25</td>
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<td>9.38</td>
<td>10</td>
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<td>8.88</td>
<td>8.28</td>
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</table>
Performance data from the simplified 12 PSR exercise indicated that participants who received training using the LASTS environment performed the exercise more successfully than those who received conventional paper based training. With reference to the CPO's evaluation criteria, Group B2 participants collectively exhibited a greater knowledge of the submarine, possessed a greater ability to recognise items, and performed the exercise with greater confidence. Given the lack of previous experience of Group B2 participants within the real world MGR, these results supported the contention that Group B2 participants were relying to some degree on the spatial representation they formed as a result of their experience within LASTS to complete the simplified 12 PSR. This in turn indicated the presence of learning transfer between the virtual and real world MGR environments.

The CPO stated during interview that there was also a difference between the techniques used by each group during the simplified 12 PSR exercise. It was observed that participants within Group B2 did not need to actually locate an item before they could confidently identify it, where as participants within Group B1 did need to do this in order to complete the exercise. The differing techniques employed by participants within Group B1 and Group B2 suggested that participants within Group B2 were utilising a more effective spatial representation of the MGR environment to locate items specific to the simplified 12 PSR. This contention was further reinforced in light of additional observations made by the CPO that stated that Group B2 participants were able to complete the exercise in approximately half the time of Group B1 participants.

Analysis of the observations made by the CPO with reference to Siegel and White's (1975) Landmark, Route, Survey model of spatial cognition suggested that participants who received paper based training were operating at the lower landmark level of spatial cognition, while those trainees who used LASTS were operating at the higher survey level of spatial cognition. The technique used by Group B1 to locate items suggested a less developed spatial representation at the route level, as a more exhaustive search was required by participants to find items. So while they seemed aware of the locations, or landmarks, they were less knowledgeable about the paths between them.

This contention was justified when considering the type of training, and therefore, spatial knowledge that was made available to participants in Group B1. This group of participants was provided with an information booklet containing a plan and cross-sectional diagram detailing the location of each item included as part of the simplified 12 PSR. A photograph of each item, taken from within the MGR on-board a Collins class submarine, was also included in the information booklet. The booklet was arranged such that the diagrams and photograph for each item were displayed on separate pages. As such, it may have been difficult for participants in Group B1 to establish routes between...
each landmark, as this would have required constant comparative reference between multiple pages in the booklet in order to be effective. This would have also made the formation of a spatial representation at the survey level difficult, as Group B1 participants would have had a reduced capacity by which to construct a complete and overall view of the locations of items included as part of the simplified 12 PSR.

Group B2 participants, on the other hand, were able to freely move throughout the virtual MGR, and were thus unobstructed in constructing paths between landmarks within the environment as they saw fit. Furthermore, the LASTS environment also allowed participants to freely construct these paths within the confines of the virtual MGR, and thus allow them to abstract their entire experience within the LASTS environment into a single spatial representation. This survey level of spatial knowledge was reinforced by the CPO's observation that Group B2 did not need to rely on traversing the environment between items in order to locate them. Rather, they were able to identify the locations of items from a single location without moving around.

5. CONCLUSION
While both LASTS and paper based trainees performed well in the simplified 12 PSR, trainee submariners using the LASTS environment demonstrated a greater knowledge of the submarine, possessed a greater ability to recognise items, and performed the simplified 12 PSR exercise with greater confidence than those trainees who received paper based training. LASTS trainees also completed the simplified 12 PSR exercise in approximately half the time of paper based trainees, which may be of future benefit to them within a combat or crisis situation. Observations made by the CPO during the simplified 12 PSR exercise further suggested that participants who had used the LASTS environment were operating with a more developed spatial awareness of the MGR environment than those trainees who received paper based training.

While the number of participants involved in the study were insufficient for the results to be statistically significant, the evidence provided did indicate that the LASTS environment was a suitable training tool for developing spatial awareness of the MGR on-board a Collins class submarine for trainee submariners. Trainees using the LASTS environment demonstrated an effective spatial understanding of the MGR environment as a result of their experience within the virtual MGR.

REFERENCES


http://www.idsia.ch/idsiareport/IDSIA-24-03.pdf


http://faculty.arch.usyd.edu.au/kcdc/ijdc/vol04/


