Developing Spatial Knowledge Through Virtual Environments

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Abstract

The Canadian Navy is facing uncertainty in platform availability to train new submariners due to operational and maintenance requirements. To address this training deficiency, the Navy has developed a first person virtual environment depicting a Victoria class submarine to reduce the reliance on a real submarine at early stages of training.

A first evaluation demonstrated that, based on learners' perceptions, the application seemed quite sufficient to allow the students to acquire knowledge of the layout of the submarine. A second evaluation comparing results from pre and post training tests measuring spatial knowledge of the submarine showed that knowledge was actually transferred from using the virtual submarine.

Results demonstrate that virtual environments of this nature can efficiently replace real platforms for the purpose of acquiring spatial knowledge of the layout of a submarine and, by extension, any ship.

1 INTRODUCTION

The Submarine Training Division of the Canadian Forces Naval Operations School (CFNOS) is facing uncertainty in platform availability to train its Basic Submarine Qualification (BSQ) students due to operational and maintenance requirements. As explained by Stone [1], access to key physical assets (such as naval vessels) for the purpose of training personnel can no longer be guaranteed. Such assets need to be at their maximum operational efficiency for obvious defence and commercial reasons. Even when they are available at the dockside, during refit for instance, they are not the most ideal of training environments, courtesy of the presence of the maintenance workforce and the fact that many compartments will bear no resemblance to the at-sea condition.

To address this training deficiency, the Navy e-Learning Center of Expertise (NeLCoE) has developed a first person virtual environment depicting a Victoria class submarine to complement and, if ncessary, replace the need for a real submarine at early stages of training. As defined by Witmer & al. [2], a virtual environment is a computer-generated simulated space with which an individual interacts. For Sebrechts [3], virtual environments can be useful for planning or mission rehearsal that involves spatial navigation. Zeltzer & Pioch [4] even argue that good simulations can systematically provide a wide range of possible training scenarios without incurring the high cost and risk of fielding personnel, equipment, and vehicles.

In fact, many studies have shown that, when used for training, virtual environments better prepared learners to move within a similar real environment than other traditional methods such as reading a map or watching a video. The results of Hussain & al. [5] show a measurable improvement in the performance of firefighters using a virtual environment for mission rehearsal over the other firefighters. Tate & al. [6] even showed an improvement of 50% in situational awareness and navigation skills for subjects using virtual environments.

Research into spatial cognition within computer-generated 3D environments [7] has indicated that there is little difference in the way spatial representations are formed in virtual environments compared to real world environments. As an example, Witmer & al., [8] demonstrated that a virtual environment can be almost as effective as real world environments in training participants to follow a designated route. An explanation of this is provided by Siegel and White [9] when they suggest that knowledge of spaces begins with noticing and remembering landmarks. So performing a task in a virtual environment should results, according to Sebrechts [10], in successful transfer to the same task in a comparable physical space.

Rossano et al. [11] mention that many of the subjects using a virtual environment reported feeling very confident in their ability to find their way around, and also indicated a sense of familiarity when tested in the actual environment. This sense of familiarity can also impact on performance on other tasks than those trained within the virtual environment. This has been observed by Tate & al. [12] when participants expressed increased confidence in performing their tasks because of familiarization with the spaces and situational awareness received through the virtual environment.

Therefore, we believe that training using virtual environment can provide a flexible way for sailors to familiarize themselves with the layout of a ship or submarine and we wanted to assess how learners perceive these training tools as well as measure their efficiency in transferring spatial knowledge? This paper provides result from two evaluations conducted using a virtual submarine in support of basic submariner training in a classroom environment.

2 METHODOLOGY

Students are normally taught about the layout of the submarine through a tour of the real submarine but for the purpose of this experiment they did it strictly by using the virtual submarine. They then wrote their knowledge test as scheduled and only then were they given access to the real submarine.

A first test was conducted with a group of 17 students consisting in Kirkpatrick's level one (reactions) evaluation. Most (65%) were under 36 years old and half (53%) had been onboard a submarine more than once before. As well, 53% played video games more than once a month. To conduct it, we asked the staff and student of the BSQ course to use the Victoria Class Virtual Submarine (VCVS) as a training aid for the portion of the course dealing with the construction of the submarine. The instructor projected the virtual submarine on the screen while the students had access to the 3D model using pre-loaded laptop computers. A few days after, they had a tour of the real submarine after which they were asked to answer a questionnaire to provide their reactions on the use of the VCVS as a training tool.

The second test consisted of a Kirkpatrick's level two (learning) evaluation with a group of 12 students who were also mostly aged under 36 (75%). 50% of this group had prior exposure to the submarine. They were asked to fill a pre-training questionnaire to establish their baseline level of spatial knowledge of the submarine. After about 3 hours of training where the instructor projected a virtual representation of the submarine to teach them about its layout, they were asked to answer the same questions in a post-training test to measure the change in knowledge resulting of training with the virtual submarine. During the training, students also had access to the virtual submarine through their laptop computers.

Finally, we compared results to the written test that is part of the course with those of previous classes.

3 RESULTS

3.1 Usage

In average, students used the virtual submarine 1.41 hours during the first week of the course. As shown in figure 1, results showed a correlation between prior knowledge of the submarine and usage time of the virtual model as the more prior experience they had with the real submarine, the less they felt the need to used the VCVS.

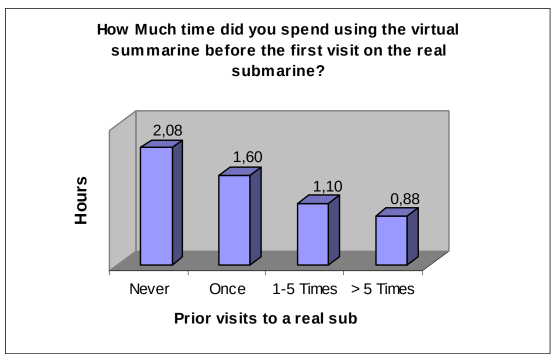

Figure 1. Usage time of the VCVS based on prior submarine experience

3.2 Fidelity

When asked if the VCVS looked realistic, all of the respondents either agreed or strongly agreed. When asked about the accuracy of the model, although everyone either agreed or strongly agreed, results at figure 2 show that the level of agreement increases with usage time passing from 67% for those who used it less than two hours to 83% for those who used it more than five hours. When we know that those who used it less are those with more experience with the real submarine (figure 1), this indicates that the more people are familiar with the real submarine, the more likely they are to find discrepancies between the virtual and the real submarines, which is quite logical.

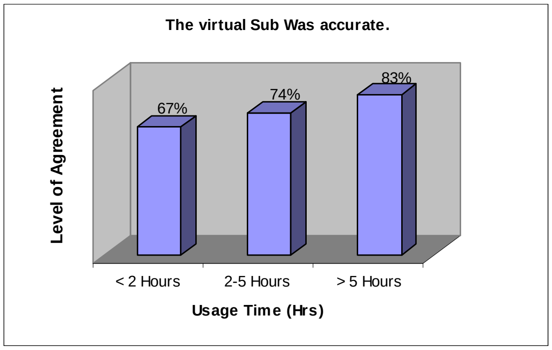

Figure 2. Perceived accuracy of the VCVS based on usage time

3.3 Knowledge Transfer

All of the respondents either agreed or strongly agreed that the VCVS helped them familiarize with the layout of a real submarine. As shown in figure 3, we found that, in general, those with less experience of the real submarine found it more useful ranging from around 90% for those who have never been on a submarine before to 75% for those who have been more than five times.

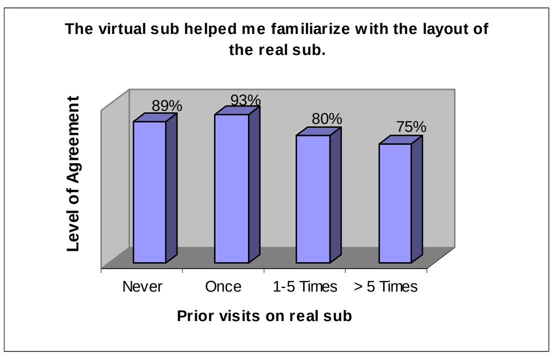

Figure 3. Perceived usefulness of the VCVS based on prior submarine experience

When asked if the use of the VCVS made them more confident on their first visit on the real submarine, 94% either agreed or strongly agreed. Even those with more experience on the submarine said it made them more confident but to a lesser extent.

Students also all agreed that the VCVS helped them find their way around the submarine on their first group visit. Figure 4 shows, as expected, that the less they knew about the submarine prior to the beginning of the course, the more they found the model useful. Results range from 100% agreement for those with no previous submarine experience to 67% for those with more than five prior visits to a submarine.

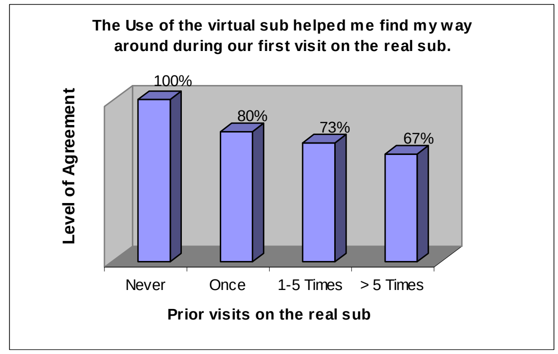

Figure 4. Perceived knowledge transfer based on prior submarine experience

While all of the respondents indicated that they benefited from using the VCVS, 6% did not think that this is an efficient learning tool. Once again, as shown at figure 5, the less experience they have with the real submarine, the more they feel they benefited from the VCVS with 100% agreement for people who have one or no prior visit to a submarine to 67% for those with more than five visits.

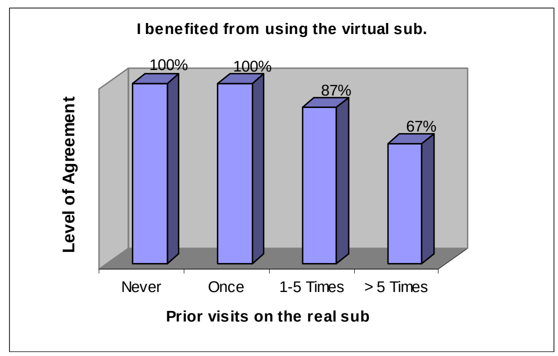

Figure 5. Perceived benefits of the VCVS based on prior submarine experience

Although students felt the VCVS helped them learn about the layout of the submarine, we wanted to verify that this impression was supported by an actual transfer of knowledge resulting from using the VCVS.

Table 1. Knowledge increase from using the VCVS

Number of corect answers			
By prior visit on submarine			
	Before	After	Increase
Never	2,0	6,3	4,3
Once	1,0	4,5	3,5
> once	6,3	7,3	1,0
By age			
	Before	After	Increase
16-25	4,0	8,0	4,0
26-35	3,6	6,6	3,0
36-45	2,0	4,2	2,2
	Before	After	Increase
Average	3,2	6,3	3,1

When comparing answers to a pre and post training test we observe, as shown at table 1, that after using the VCVS for less than 3 hours the number of correct answers increased in average of 3,1 out of 10. The increase seems significantly more important for those students who have never been exposed to the submarine before (4,3) than for those who have been exposed once (3,5) or more than once (1,0). As well, the knowledge increase gets smaller with age going from 4 for the 16-25 age group to 3 for the 36-35 to 2,2 for the 36-45.

Finally, we did not see any significant difference between the results to the written tests of the groups we observed and those of previous classes.

4 ANALYSIS

Knowledge transfer is probably what differentiates virtual learning environments from commercial games. The first observation we make from that study is the strong positive feedback received from the students. Based on learners' perception, the virtual environment provided students with the feeling they acquire spatial knowledge of the submarine. This impression of learning was also supported by instructors who reported that students who used the VCVS seemed to be more confident than those of previous course serials on their first visit to the real submarine.

Most important is that this feeling of learning something results in an actual knowledge transfer as we demonstrated through the pre and post training evaluations which indicate that knowledge is actually transferred from using the virtual environment for as little as 3 hours. Such results can only be predictive of more knowledge being transferred as usage time increases since repetition increases retention. Therefore, extended use of a virtual environment should improve the mental representation of the environment.

While VCVS usage decreases with students' prior experience onboard a real submarine, we understand that the more students know the submarine, the less they need the virtual environment achieve the required level of spatial knowledge. However, this is also an indication that VCVS represents a valuable alternative to compensate the lack of experience for those who had few or no chances to access a submarine prior to the course. Since less experienced students reported having benefited the most from the model, this indicates that a virtual environment may also help all students achieve a common level of spatial knowledge early in the training, whatever their prior experience.

One of the issues we observed however with this kind of learning tool is that individuals with more experience aboard the real ship seem to expect more physical fidelity from the virtual model. This may be due to the fact that their mental representation of the environment is, in some instances, more detailed than what the model displays. Since, in order to reduce development time, we omitted some details such as valves, pipes and wires it is possible that they did not find objects they were remembering from their visits on the submarine.

This is an indication that, for more experienced target audiences, we must ensure greater physical realism which somehow contradicts Daly & Thorpe [13] who argue that realism can detract or deter from the focus of the training and in fact result in less effective training. Our findings seem to demonstrate that, experienced learners may be distracted by the lack of physical fidelity if they do not find or recognize things they expect to see in the model.

In the end however it seems clear that, despite its limited interaction capabilities and some physical inaccuracies, the VCVS has proven to be an efficient learning tool. Future improved VCVS versions can only provide more benefits than the trial versions used for this study.

5 CONCLUSION

These trials showed without a doubt that virtual environment can efficiently replace real platforms for the purpose of developing spatial knowledge of the layout of a submarine and, by extension, any ship. Not only did learners have the impression to learn and benefit from the virtual environment, they actually significantly improved their level of spatial knowledge by using it for only a small amount of time.

There is however a requirement to measure how much of this knowledge is actually transferred to the real environment and what impact this transfer can have on students' performance once on the job.

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