Evaluation of performance in emergency response scenarios: a virtual environment skill retention study

By

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A Thesis submitted to the

School of Graduate Studies

In partial fulfillment of the requirements for the degree of

Master of Engineering

Faculty of Engineering and Applied Science

Memorial University of Newfoundland

Submission:

May 2018

St. John's

Newfoundland and Labrador

Abstract

The research described in this thesis investigates the longitudinal retention of skills attained by naïve subjects who had completed a virtual induction training. This work is a continuation of the original induction training conducted by Smith & Veitch (2017, 2018). The original induction training introduced participants to a "virtual offshore platform" where they were taught basic safety and egress procedures. After a period of 6 to 9 months, the participants were re-exposed to the virtual environment and tested again. The researcher has hypothesized that participants will demonstrate skill fade over this period, and there will be a difference in repeated measures between exposures. Retention of key concepts were evaluated to determine where skill fade was most prominent, and the amount of retraining required to bring participants back to competency was recorded. The experimental results demonstrated that skill fade was most prominent in foundational testing scenarios where participants were first re-exposed to each learning objective. Further, the results indicated that the participants were quickly re-trained to post training competency after initial re-exposure to the environment. The findings of the experiment support the research hypothesis.

Acknowledgment

I would like to thank my graduate advisor Dr. Brian Veitch. I am very grateful for the opportunities and support that he has provided to me throughout my program. Through conducting this research, I feel that I have expanded my mind and developed a capacity for critical thinking, which will help to be a more effective engineer and leader. This research project has been the opportunity of a lifetime, and I would not have been successful without his guidance.

I would like to acknowledge the support of the entire Memorial University Safety at Sea research team. Without their development of the AVERT platform, and their technical support I would not have been successful in this endeavor. A special thank you is due to Jennifer Smith. This thesis has been built upon her research, and her guidance has been invaluable.

Thanks are also due to my co-investigators, Allison Moyle and Sinh Duc Bui. They provided continuous support and encouragement throughout the project. The journey was richer with their company and insight.

Most of all I would like to thank my parents Jim Doody and Glenda Lannon. Their unwavering support in pursuit of my education had helped me become the man that I am today.

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List of Acronyms, Abbreviations, and Indicators

AVERT	All Hands Virtual Emergency Response Trainer
Avg.	Average
B#-S#	Training Block X, Scenario Y
CAPP	Canadian Association of Petroleum Producers
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
DoF	Degrees of Freedom
EER	Escape, Evacuation and Rescue
FPSO	Floating Production Storage and Offloading
GPA	General Platform Alarm
HMD	Head Mounted Display
LO	Learning Objective
ML	Mastery Learning
PAPA	Prepare to Abandon Platform Alarm
SBML	Simulation Based Mastery Learning
SMEs	Subject Matter Experts
Std. D.	Standard Deviation
Std. Error	Standard Error
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TA1	Alarm Testing Scenario 1 (Test 2)
TC1	Continually Assess Situation Testing Scenario (Test 3)
TE	Testing Environment
TE1	Environment Testing Scenario (Test 1)
TH1	Hazard Test Scenario (Test 4)
TTC	Trials to Competence
VE	Virtual Environment

Chapter 1: Introduction

1.1: Relevance of Work

The processes associated with offshore natural resource recovery are known to be safety-critical. Offshore installations may be situated hundreds of kilometers offshore, making them remote and difficult to respond to in emergency situations. Given that these operations have the potential to become hazardous, it is vital that personnel are trained to respond effectively to emergencies.

Offshore operations in Newfoundland & Labrador are monitored by a variety of government bodies including Transport Canada, and the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). The regulations put in place by these regulatory bodies dictate emergency response and preparedness regulations for operators, as well as minimum competency requirements for offshore personnel. These regulations help to ensure that risks are appropriately mitigated while production facilities are in operation. These emergency operations are known as escape, evacuation, and rescue (EER) procedures.

As prescribed by the authorities above, all personnel who are new to an offshore environment must complete safety induction training. This training is used to familiarize personnel with the work environment, as well as site specific procedures. The content of this training generally includes installation emergency alarms, muster station locations, locations of life saving equipment, and drill schedules. These requirements also apply to any personnel who have been absent from the installation for a period of 6 months or greater (Canadian Association of Petroleum Producers, 2015). This safety induction is critical as it ensures that personnel are prepared in the event of an emergency scenario.

Induction training is often administered through classroom sessions, orientation videos, and supervised shifts, while relevant safety critical skills are practiced through regularly planned drills. The frequency of drills regarding safety inductions are also regulated. The standards of practice dictate that offshore personnel must practice fire drills weekly, man over-board drills monthly, and platform abandonment drills every three months (Canadian Association of Petroleum Producers, 2015).

These methods allow for offshore workers to practice safety protocols but can be restrictive. Certain aspects of the procedures cannot be reproduced in a drill as it would expose personnel to danger. An alternative training approach to conventional offshore induction training is through virtual environments, or simulators. A virtual environment allows for an ecologically accurate representation of the workspace, as well as exposure to hazard scenarios that personnel would otherwise not be able to experience. This methodology offers an effective and convenient way to educate offshore personnel and has the potential to reduce the time required to train personnel to competence.

1.2: Research Objective

The purpose of this research was to investigate the longitudinal retention of skills attained by naïve subjects who have completed a virtual induction training. The original induction training conducted by Smith & Veitch (2017, 2018) introduced subjects to a "virtual platform" similar in layout to existing installations and educated participants on relevant EER procedures. In this study, participants were re-tested after a period of 6 to 9 months, the same subjects were re-exposed to the environment and tested again. Retention of key skills and knowledge was assessed, including the extent to which their skills had declined in each specific learning competency, as well as the extent of additional training required to bring them back to full competence in EER procedures.

1.3: Hypothesis

The hypotheses for this research have been stated in the form of null and alternative. The null hypothesis states that the mean performance score of the sample taken from Smith & Veitch (2017, 2018) will be equal to the mean of the retention experiment. The alternative hypothesis states that the mean performance score between the two groups will not be equal. In other words, this experiment intends to determine if participants who complete an induction training within a virtual environment can demonstrate post training levels of competency after the retention interval. The expected result is that participants will demonstrate skill fade over this period.

Performance score is not the only measurement used in this thesis. Trials to competence is another indicator of participant competence. For this performance indicator, the null hypothesis states that the number of attempts taken to be successful in Smith & Veitch's (2017, 2018) experiment will be the same as the number of attempts required to be successful in the retention experiment. Stated concisely, the second performance measure will evaluate if the repeated measure varies between experiments. The expected result is that the null hypothesis will be rejected.

Table 1: Null and Alternative Hypothesis

Null Hypothesis (Performance):	$H0\_p$: $\mu 1 = \mu 2$
Alternative Hypothesis (Performance):	Ha_p: $\mu 1 \neq \mu 12$ $\mu 1 > \mu 2$ or $\mu 1 < \mu 2$
Null Hypothesis (Trials to Competence):	$H0\_t$: X1= X2
Alternative Hypothesis (Trials to Competence):	Ha_t: X2 $\neq$ X1

1.4: Experimental Basis

The experiment detailed in this thesis was conducted using the AVERT (All Hands Virtual Emergency Response Trainer) virtual environment (VE) and builds on the research conducted by Smith & Veitch (2017, 2018). In Smith's initial VE study (Smith, 2015), the potential training benefits of the AVERT platform for virtual emergency response on EER procedures were examined. In Smith's experiment, participants were taught specific learning objectives. Training was delivered through a combination of tutorial slides, videos demonstrating egress routes, and free exploration time within the virtual environment. Participants were separated into two groups: the first group received no extra practice time within the training environment; the second group was provided with extra training scenarios. At the end of each scenario, all participants were provided with automated feedback regarding performance. The results of this experiment showed that competence was not demonstrated in the simulation environment and that competence in key learning objectives was not reached. As a result, the training curriculum was revised to reflect the mastery learning (ML) approach (Bloom, 1968). The efficacy of the mastery learning pedagogical approach was subsequently investigated in another experiment in AVERT (Smith & Veitch, 2017, 2018). In this experiment, participants were required to demonstrate competency in learning objectives before being able to proceed to further training. Dedicated training scenarios were developed to demonstrate and reinforce specific learning objectives, and full competency was required for each learning objective in each scenario. At the end of each scenario, detailed feedback regarding each learning objective was provided, and participants were given details regarding how the learning objectives were not met. If a scenario was not completed successfully, the participant was required to repeat the scenario until competency was demonstrated. The results of this experiment demonstrated that the mastery learning approach significantly improved the performance of participants in the dedicated learning objectives.

A question arising from the experiment conducted by Smith & Veitch (2017, 2018) relates to the longer-term retention of competence over an extended period without practice. The present thesis addresses this question, specifically for the case of naïve learners who initially acquired their competence though the mastery learning approach.

Chapter 2: Literature Review

For over a decade, research on the teaching capacity of virtual environments has been under investigation. In this chapter, literature relevant to the use of virtual environments for skill acquisition and retention will be reviewed.

2.1: Virtual Environment Fidelity for Training

2.1.1: Virtual Environments (VE) as a Teaching Tool

The use of virtual environments for training purposes is a relatively new field of study, and investigations in this field cover a wide variety of industries. Kinateder et al. (2014) conducted a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis on the topic of virtual reality for research into human behavior in fire related environments. In their analysis, a variety of experiments were compared, including those completed in laboratory settings, field studies, drills, and case studies. The primary finding was that VEs offer a powerful approach to analyzing participant behavior as it offers full control over the scenario conditions. However, they highlighted the need for further validation studies. The overall conclusion was that virtual environments offer a promising complementary research method to better understand human behavior in fires.

This conclusion is supported by the experimental research by Kobes et al. (2010) regarding the use of virtual environments for route selection of participants in hotel fires. Kobes reported a two-phase experiment. The first phase involved the use of a virtual environment that was modelled after an existing hotel. Participants completed three scenarios: a simulated fire drill, a scenario with smoke blocking the main exit, and a scenario with smoke blocking the main exit where the exit signs were placed at ground level. The second phase replicated the scenarios from the VE in the real hotel setting, thereby allowing for a direct comparison of evacuation results in all three scenarios. The results demonstrated that in the basic fire drill there was no significant difference in route selection between the VE group and the real environment group, and in the scenario where smoke blocked the main entrance there was also no significant difference between groups. However, in the low exit sign scenario, a significant difference was found for exit choice, where participants tended to evacuate to the nearest exit in the real environment, while participants in the VE selected an alternative route. The researchers concluded that virtual environments can be considered valid for way-finding research.

Further research has gone into the exploration of VE for safety training in niche environments surrounding fire safety. An example of this is the meta-analysis completed by Williams-Bell et al. (2015) regarding VE and serious games for fire fighter training. Their research demonstrated that VE and serious games offer an ecologically correct environment in which to practice emergency decision making. This approach also offers a more cost-effective means of providing training and does not place trainees in danger. One of the issues flagged with the training methods reviewed is that there were no progress tracking methods to ensure that learning outcomes were being achieved within the simulation. Further, the level of physical exertion and environmental stimuli are not accurately represented in VE, which has a significant impact on the training validity for the fire-fighting profession. This suggests that VE be reserved for recreation and training of the decision-making processes that fire-fighters may see while in real life environments. This position is also advanced for other domains, as demonstrated in the article by Bellotti et al. (2013). The literature also calls for longitudinal studies to be conducted, where the long-term retention of skills acquired in VEs are examined (Girard, Ecalle, & Magnan, 2012).

Other industries have also investigated VE for training purposes within the safety domain. Simulation training for navy submarine operations was conduced by Magee et al. (2012) to determine the efficacy of VEs for teaching emergency drills. Two experiments were conducted. The first compared experienced personnel to novices who were initially trained in VE and were then asked to complete the emergency drill in real time. The second experiment compared the group trained in the VE from the first experiment, to a group trained via a classical method of demonstration. The results of the first experiment showed that the novice learners who had been instructed in VE took significantly more time to reach competence than those who had previous experience onboard submarines. However, the second experiment demonstrated that the VE had instilled an elevated level of spatial knowledge when compared to those who had completed the VE training, and that those who had been trained in the VE outperformed those who were given a traditional demonstration.

Within the domain of process safety there has been research into the training effectiveness of VE. Limongelli et al. (2012) developed a training tool that targets routine tasks commonly completed by operators within process industries. The example used was the replacement of a circuit breaker. This simulator included a virtual whiteboard where the interface is demonstrated, and the operator has the capacity to complete the procedures required for the maintenance item. This simulator included a virtual tutor that could be implemented in several ways. In the example presented, the tutor waits for the mistake to occur and then alerts the operator to the error. This is followed by a demonstration of the correct operation.

Manca et al. (2013) conducted a study that used stereoscopic 3D to provide operators with realistic operations training. This stereoscopic experience was paired with a process plant simulator. The combination of these simulation tools allowed Manca et al. (2013) to control process data inputs and examine how the operator's response to emergencies would impact process safety within the simulation. This study was followed by an analysis conducted by Nazir et al. (2015) that examined conventional classroom education versus VE training. This experiment demonstrated that those trained in VE outperformed the classroom group in distributed situation awareness (decision making).

2.1.1.1: Within the domain of this experiment

The domain of the experiment detailed in this thesis falls within the field of offshore induction training through use of virtual environments. Mcgrath (2012) conducted an experiment where a virtual induction training module was administered to explore trainee capacity to respond to hazards in VEs. After completing the instructional module of safety protocols, participants completed a VE scenario where they were required to navigate from one side of the installation to another. In this scenario, participants were required to observe and assess the best route based on hazard identifiers placed throughout the scenario. At the end of the scenario, feedback was provided to the participant based on the things that they did or did not do correctly.

2.2.2: Success Using Mastery of Learning in Simulation Training

Research investigating simulation-based mastery learning (SBML) has been expanding over the last decade with most being conducted within the medical field. McGaghie et al. (2014) conducted an analysis on the topic with regards to the techniques used within the domain of medical education. This analysis critically reviewed 23 medical education studies involving the mastery learning approach and reached the conclusion that SBML is a teaching method that should be adopted across the medical education discipline. SBML has the capacity to reduce the current system's reliance on apprenticeships, be incorporated with autonomous feedback systems, and reduce the overall cost associated with training, while improving patient care.

Griswold-Theodorson et al. (2015) extended the conclusions of McGaghie et al. (2014) in their examination of SBML clinical outcomes. Fourteen studies were examined where pre/post performance was analyzed. Many of the studies targeted procedural knowledge acquisition and implementation. The results demonstrated improved performance, task success, as well as a reduction in procedure times, complications, and patient discomfort. The article concludes by noting that the impact of SBML on longitudinal skill retention and teamwork requires examination.

A recent investigation involved mastoidectomy skills acquired through simulation training on novices (Andersen, 2017). Andersen investigated performance, massed versus distributed practice, and retention of skills attained through SBML. Andersen (2017) concluded that the SBML method had a direct impact on performance when transferring skills from simulation to real procedures.

2.3: The Retention of Skills

2.3.1: Skill Retention in Physical Environments

The concept of overlearning describes the continued practice of skills after reaching 100% competence in their execution. Most people expect that continued practice over a brief period will ensure that the skill is better retained, although evidence to the contrary has been determined through experimentation. Rohrer et al. (2005) conducted two experiments where participants were asked to memorize word pairs to determine the effects that overlearning had on retention at varying intervals. The results determined that while retention remains very high during the first few days for those who overlearn the material, a high degradation in recall capacity occurs after a period of 3 to 4 weeks. While the overlearning group out-performed the control group at both initial and longitudinal recall, the deviation after the longitudinal period was marginal. In this article, the author acknowledged that the tasks completed were simple and that more complex tasks may have a different impact on retention.

Research conducted by Walsh et al. (2013) suggested that the proficiency obtained at the end of training is the best indication of skill retention. In their experiment, forty-two participants were recruited to complete a single-handed double-square knot. Participants were asked to watch a five-minute video that gave verbal and visual instruction on how to tie the knot. The participant sample was split into three groups of equal size with different success criteria: tying the knot in 10, 15, and 20 seconds respectively. Competence was reached when the knot was completed within the designated time frame and all were completed from a starting position. Participants in the 10 second group had a significantly greater number of attempts when compared to the other training groups (n=23.2(10 sec), n=12.6(15 sec), n=10.0(20 sec)), where n is the mean number of attempts to success. During a retention test one week later, it was noted that the time to success of the 10 second group was much faster (m=14.8(10 sec), m=24.1(15 sec), m=23.7(20 sec)) than the other groups, where m is the mean number of seconds to complete the knot. This result suggests that training completed to a competency level has a greater impact on the retention of procedural skills than training provided within a certain time frame. Experience based paradigms have been criticized as they are known to produce varying levels of competence in trainees by enforcing a minimum number of training hours, as opposed to assessing task competency on a per learner basis (Gallagher et al., 2005). This approach does not adjust for different learners and as a result over-trains those who become competent quickly and undertrains those who learn slowly.

More complex tasks related to procedural knowledge have also been examined. Sanli and Carnahan (2017) conducted a literature review regarding the long-term retention of skills within the domain of multi-day training, and examined resuscitation, military training, and marine offshore safety and survival. The review revealed that practical skills decayed more rapidly than declarative knowledge, and that simple practical tasks demonstrated elevated levels of retention when compared to complex and multi-step tasks. The authors also noted that skill level and on the job exposure to tasks have an impact on overall retention. As noted above, the finding by Walsh et al. (2013) supports the conclusion that participants trained to higher standards of performance retain tasks better. Sanli and Carnahan (2017) also cited several studies that revealed the same conclusion. Further, research participants who had multiple exposures to training opportunities were found to perform better than their peers. Sanli and Carnahan (2017) also reported that, based on available literature, a six-month retention interval is the best that can be expected for complex tasks in a multi-day training context.

2.3.2: Skill Retention in Virtual Environments

Chittaro and Buttussi (2015) examined the retention of skill exhibited by participants immediately after training, and again after one week (with a verbal survey). In their experiment, test groups learned how to evacuate an aircraft in the event of an emergency. The first group made use of a Head Mounted Display (HMD) immersive serious game, while the second group learned from a traditional safety card. Both groups saw strong post-test results, but the HMD group had a higher level of retention at one week.

In an experiment conducted by Smith et al. (2016), the effects of virtual reality in decontamination simulations were examined. In this study, the participants were split into two groups. Participants in each study completed an online teaching module and then were asked to either review written instructions (control) on the decontamination procedure, or complete a module within the virtual environment. Participants in the virtual environment were found to have better performance immediately after training, faster completion times, as well as improved performance on the post performance cognitive test. After a period of 5 to 6 months, participants were revaluated in terms of their capacity to complete the decontamination procedure. Performance was determined to be better in the control group than in the virtual environment group. The completion time for the simulator group remained better than the control group, while the post-performance cognitive test showed no difference in performance between groups.

There has been significant investigation into the retention of complex and longitudinal skills within the medical training industry, especially using simulation technology. An example of such research is the investigation conducted by Sui et al. (2016), which focused on the acquisition and decay of surgical skills in virtual environments. Sui et al. (2016) approached this research with the goal of developing an adaptive training simulator that can model the learner's skill acquisition and decay and then develop a training regime to maintain competency. Participants in the initial experiment using this trainer completed three sessions: a baseline, a session after one week, and a session after one month. The results determined that skills were quickly attained in the baseline and that notable decay was observed over subsequent sessions. However, decay of skills was noted to lessen with practice.

Atesok et al. (2016) completed a meta study examining the use of simulation training for orthopedic surgery. Several studies were cited with varying retention intervals and practice. The most relevant articles to the present work are by Stefandis et al. (2008) and Maagaard et al. (2010). In both cases, participants were restricted from additional training after initial exposure and tested at a relatively long retention interval. Stefandis et al. (2008) examined an interval of 5 months, while Maagaard et al. (2010) examined intervals at 6 and 18 months. In Stefandis' study, the simulator group outperformed the control group, but decreased proficiency in laparoscopic suturing was noted over time. In Maagaard's study, the performance of the novice group remained high at 6 months but deteriorated to pre-training levels at 18 months. The research completed by Varley et al. (2015) and cited in Atesok's article also supports this conclusion, although their research was conducted at shorter intervals (1 and 3 months). An interesting observation comes from other studies cited in Atesok's article regarding the retention of skills where participants were provided with opportunity to practice skills within the simulation environment. Studies completed by Jiang et al. (2011), and by Ortner et al. (2014) demonstrated that performance at prolonged retention intervals (at 6 months and 8 months, respectively) can remain at immediate post-training levels if opportunity for practice is provided. Atesok et al. (2016) posited that the most likely way to achieve meaningful skill retention is through "spaced rehearsal", where the amount of time between practice sessions continues to increase. It was also noted that even minimal practice prior to required performance can result in significantly improved performance even after a lapse of skills (Hein et al., 2010). This conclusion regarding "spaced rehearsal" (otherwise known as distributed practice) is also supported by Andersen's (2017) analysis regarding skill retention in laparoscopic surgical simulation (i.e., distributed practice yields better long-term retention than massed practice).

Chapter 3: Methodology

3.1: Experimental Overview

3.1.1: Experimental Overview

The retention study was designed to measure the retention of skills after a 6-month interval and to compare the retained skills to the benchmark performance established in Smith & Veitch's (2017, 2018) earlier SBML study. Thirty-eight participants participated in the retention study. All participants were recruited from the pool of 55 people who participated in Smith & Veitch's (2017, 2018) SBML experiment, which is described in detail in section 3.1.2 below. An overview of Smith & Veitch's (2017, 2018) SBML experiment is shown in Figure 1. Each participant in the retention study completed his or her involvement in a single session. The session consisted of an initial habituation to the technology, followed by a series of testing scenarios.

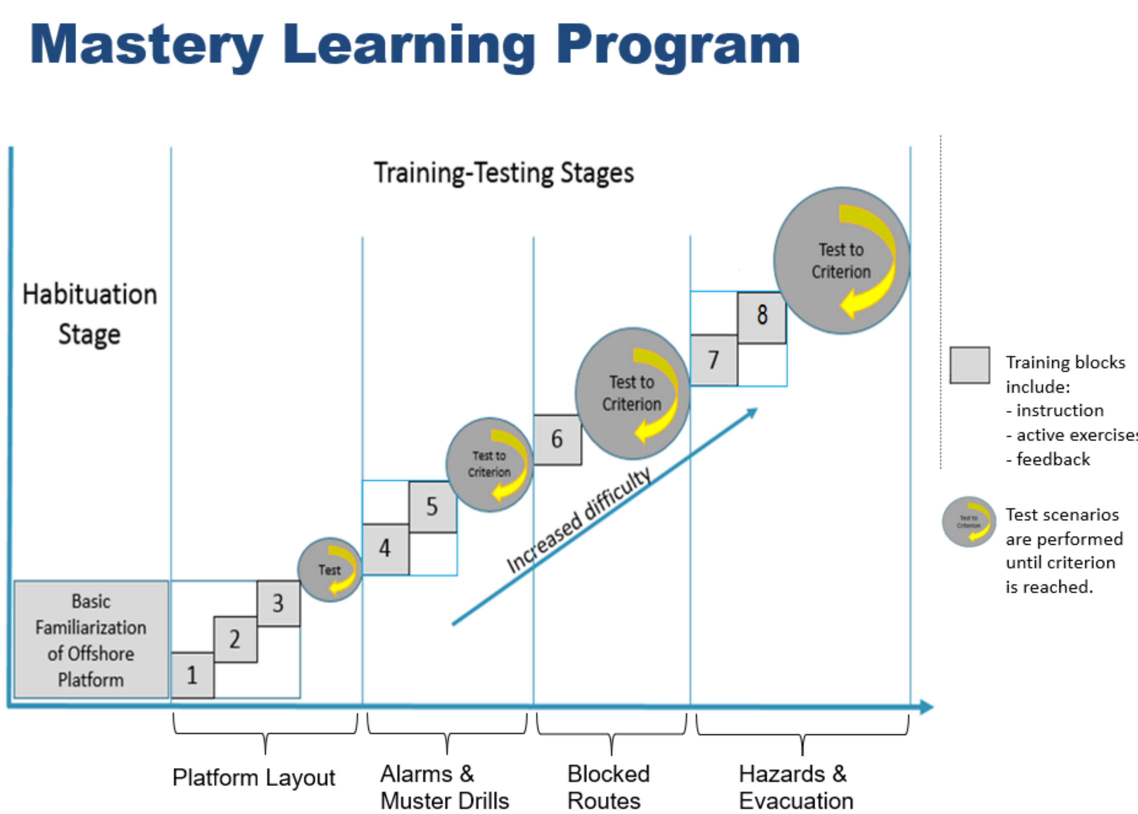

Figure 1: Simulation Based Mastery Learning Training Overview (Smith & Veitch, 2017)

Retention of the skills attained during Smith & Veitch's (2017, 2018) initial SBML training was evaluated using identical testing scenarios from the SBML experiment. Participants who were not successful in completing a test scenario were re-trained to competence before moving on to more advanced testing scenarios. Each participant's retraining consisted of one or more training scenarios based on the error made during the evaluation. The scenarios selected for a given participant's retraining were based on their performance in the test scenario and reflected a learning objective that required retraining. The retention experiment retraining methodology is demonstrated in Figure 2.

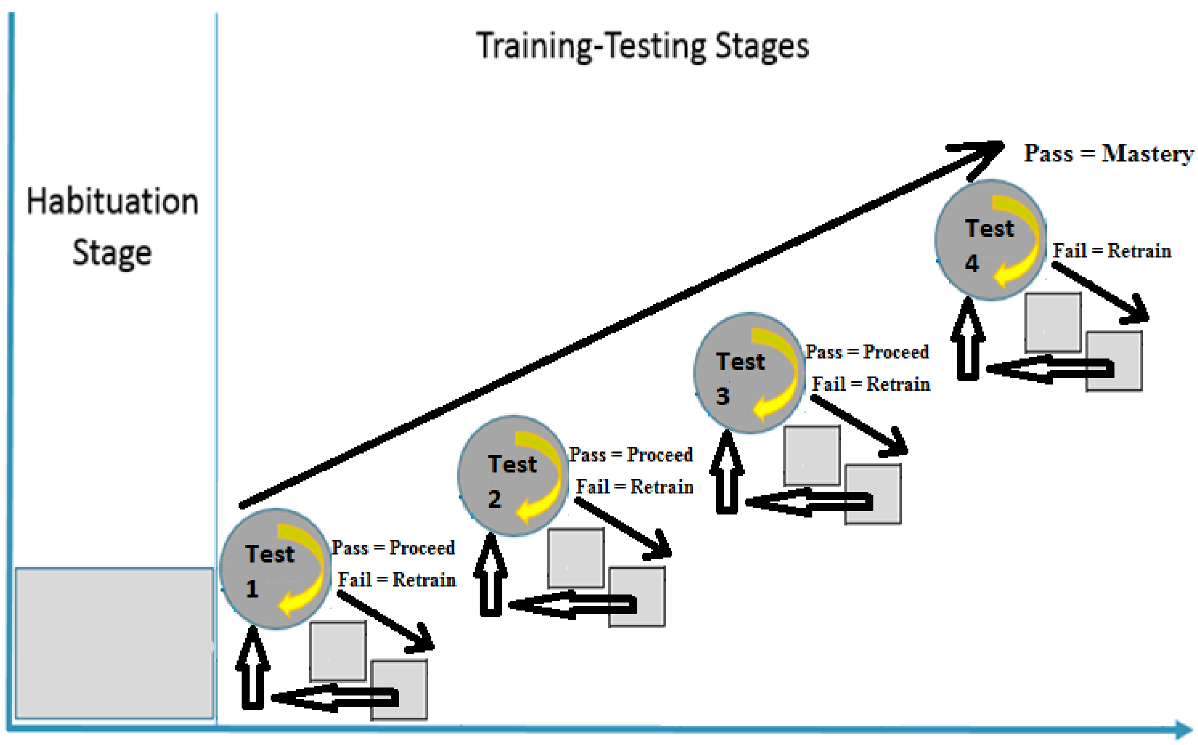

Figure 2: Experimental Training Procedure (Retention Experiment)

A matrix for each testing scenario was developed to link the retraining scenarios to the errors made. This approach ensured consistent treatment amongst participants. The adaptive training matrices developed for each testing scenario are presented in Figure 5 through Figure 8 in Section 3.3.3.

3.1.2: A Review of Smith & Veitch's (2017, 2018) SBML Experiment

The simulation-based mastery learning (SMBL) experiment completed by Smith & Veitch (2017, 2018) was discussed briefly in Section 1.4. Additional details are presented here to demonstrate how the retention study builds on the SBML work. Smith & Veitch's (2017, 2018) foundational experiment was comprised of four training modules, each dedicated to the introduction of new skills required for successful performance within the context of the VE. A brief description of the training blocks is provided below:

- Habituation: This training block was comprised of three scenarios timed to a maximum of five minutes and focused on teaching participants the basic skills required to operate in the VE. These skills included familiarization with the controller layout, basic navigation, object interaction, and use of in-game items.
- Training block 1: This training block focused on teaching participants how to navigate the environment, as well as on basic safe practices. The block was comprised of three training scenarios that focused on platform layout, effective route selection, and safety protocols regarding running and use of fire tight doors.
- Training block 2: This training block focused on teaching participants how to respond to platform alarms, as well as appropriate steps required in the mustering procedure. It was comprised of two scenarios; learning outcomes included identifying alarms and responding appropriately.
- Training block 3: This training block focused on teaching participants how to respond in scenarios where their normal safe evacuation paths were obstructed.
- Training block 4: This block was comprised of a single training scenario focused on teaching participants how to respond to hazards that were introduced into their path. This training block differed from block 3 as the hazards were present in the

environment and the participants could interact with them. The block was comprised of two training scenarios and focused on response to dynamic environmental changes and use of personal protective equipment (PPE).

Smith & Veitch (2017, 2018) provided training slides at the beginning of each teaching scenario, allowing participants to become familiar with the scenario contents and skills required to be successful. After each scenario, participants were given detailed feedback on their performance, which detailed the learning objectives they completed successfully, and the ones that they were unable to complete.

To proceed from one training scenario to the next, participants were required to meet a minimum level of competency in the learning objectives for the training scenario. Failure to meet the minimum criteria of a learning objective resulted in the participant being required to repeat the scenario. Smith & Veitch (2017, 2018) measured participant performance through performance scoring and trials to competence. Full details of the measured learning objectives are presented in Section 3.3 of this thesis.

3.1.3: The Retention Experiment Testing and Retraining Curriculum

This experiment is based on the premise that time absent from the training environment will have an impact on the number of attempts taken to be successful (trials to competence) and participant performance. Therefore, the independent variable in this experiment is time, and the independent variables are performance & number of required attempts.

Each testing scenario used in the retention experiment contained dedicated learning objectives that were used to capture each participant's level of retention (performance). These same learning objectives were used in Smith & Veitch's (2017, 2018) experiment. Participant performance in these objectives was scored using a rubric. Each learning objective was allocated a point value that was set by the experimenter and was scored based on its relative importance to the training outcomes.

Each session started with a habituation scenario, the purpose of which was to re-introduce the participant to the teaching environment. All experimental runs were completed using a basic desktop computer set-up where participants used an Xbox 360™ controller and a single monitor to complete the simulation. The habituation scenario re-introduced participants to basic controls required for navigation in the environment, how to collect and use in-simulation items, as well as use menus. During the habituation stage, participants were not timed, nor were they scored for performance. To ensure that this initial exposure to the environment did not have an impact on the participant's spatial awareness of the testing space, the habituation stage was restricted to an area within the VE where the testing scenarios did not take place.

After successfully completing the habituation scenario, participants proceeded to the testing phase. As shown in Figure 2, participants made an initial attempt at a testing scenario and were evaluated on their ability to meet the scenario's learning objectives. For the participant to successfully proceed from one testing scenario to the next, s/he was required to demonstrate a threshold level of competency in each learning objective. If a participant was unable to demonstrate competence in all learning objectives, s/he was provided with detailed feedback regarding the error(s) made and then directed to complete training scenario(s) that best targeted the specific knowledge gap. These training scenarios were the same used during Smith & Veitch's (2017, 2018) experiment. After completing the training scenario(s), participants were given another opportunity to attempt the testing scenario. This cycle continued until the participant was successful in the scenario, at which time s/he was permitted to proceed to the next test.

To ensure that the information provided to each participant at the beginning of the experiment was consistent, a script was prepared that covered the information each participant was required to understand prior to testing. After this initial briefing, participants began the study; information provided beyond that point was restricted to feedback given from the software. Intervention only occurred during re-training scenarios where known procedural hurdles with the AVERT virtual environment were identified. The script is presented in Appendix A.

To ensure that participants who required re-training received consistent treatment, adaptive training matrices were developed for each testing scenario. The matrices were used to identify additional training scenario(s) based on the error made. For example, in the event a participant did not pass a testing scenario on the first attempt, s/he was directed to do a training scenario until competency was demonstrated. The testing scenarios, training scenarios, and training materials used for the retention study were taken directly from Smith & Veitch's (2017, 2018) study. This ensured that subjects were exposed to identical environments and scenarios, allowing for a direct comparison of performance without environmental variation. A sample adaptive training matrix is shown in Figure 3 below and details regarding the development of adaptive training matrices are presented in Section 3.3.3.

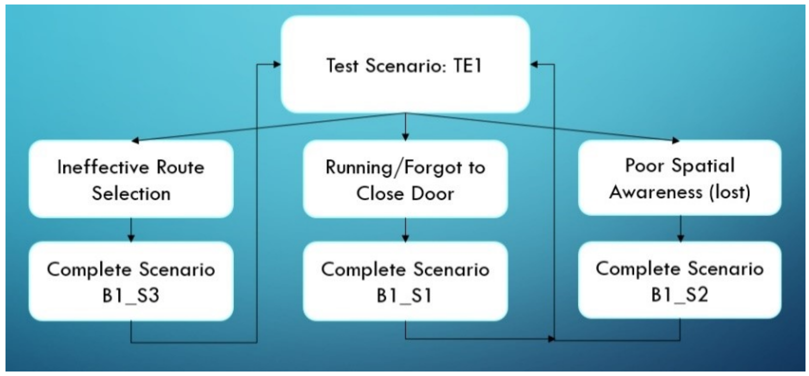

Figure 3: TE1 Adaptive training matrix

3.1.4: Sample Size and Description of Participants

The experiment was designed such that a paired sample statistical analysis could be conducted between Smith & Veitch's (2017, 2018) data set and the retention data. To ensure reliability of data analysis, the minimum required sample size for this experiment was set at 30 participants. This value is derived from the Central Limit Theorem, which states the mean of a sufficiently large data set composed of independent random variables will tend towards a normal distribution, despite the fact the independent variable themselves may not be normally distributed. Although it was unknown if the data would follow a normal distribution, the experiment was designed with this concept in mind to improve the statistical power of the paired sample statistical test conducted. To ensure consistency of the paired sample statistical test, the scoring rubric used throughout the Retention study was identical to the rubric used by Smith & Veitch (2017, 2018).

Participants from the original study who had already successfully completed the training were the only participants eligible to complete the retention study. During the period between testing in the SBML study and the subsequent testing in the retention study, participants were not exposed to the AVERT software and were not given the opportunity to review information relevant to the training. Only those who agreed to be contacted for future research studies after completing the SBML experiment (Smith & Veitch, 2017,

2018) were included in the potential participant sample pool for the retention experiment. Forty-eight of fifty-five participants who completed Smith & Veitch's (2017, 2018) experiment indicated they could be contacted for the longitudinal study, of whom 38 returned to participate and 36 were included in the dataset. Two participants were considered to be outliers as they fell outside of the retention interval of 6 to 9 months and were excluded from the dataset.

3.2: The AVERT Simulator and Integrated Learning Management System

3.2.1: AVERT Environment

AVERT is a first-person simulation environment designed to provide a realistic representation of a real workplace. In this application, AVERT has been designed to provide naturalistic training within the context of a Floating Production Storage and Offloading (FPSO) vessel. For this experiment, training scenarios were designed that reflect the learning objectives identified as important for offshore safety induction training and emergency egress. An advantage of the AVERT environment is that participants may be exposed to hazardous scenarios, which would otherwise be impossible to re-create in a real environment without exposing personnel to dangerous hazards.

3.2.2: Learning Management and Automated Brief/Debrief System (Data Collection)

One of the other benefits of the AVERT platform is that it can also convey important safety information and provide feedback on the user's performance. This is accomplished through the automated briefing and debriefing system incorporated within the AVERT software. Prior to completing any training scenario, a set of lecture material can be delivered to the user to prepare them for the learning exercise. A sample tutorial slide is demonstrated in Figure 4 below. This information can be conveyed in the form of presentation slides and diagrams.

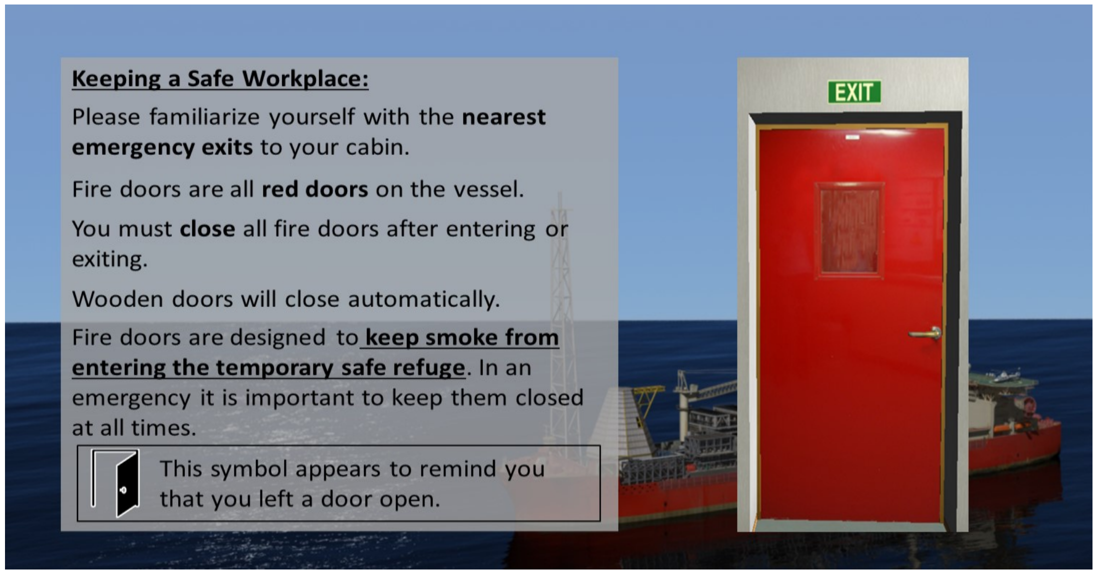

Figure 4: Sample Tutorial Slide from AVERT Training Environment

Upon completing the scenario, the automated feedback system provides the user with a breakdown of the specific learning objectives that the scenario incorporated, and an assessment of the user's performance, including whether the user met the minimum competency required for success in the scenario. Success in the scenario was only achieved through successful completion of all learning objectives. Each learning objective was shown to the user after completion, along with a list of items that they failed or completed successfully. Each scenario automatically produced a report file in a .txt format, which provided time-stamped information regarding the user's activities within the virtual environment. Information provided in this file includes physical translation and rotation within the environment, items and objects interacted with in the environment, change in alarm states, and important checkpoints.

3.3: Procedure (Simulation Testing and Adaptive Training)

3.3.1: Testing Scenarios, Learning Objectives, and Scenario Scoring

As discussed in section 3.1, participants were invited to complete the study only if they had successfully completed the training in the experiment conducted by Smith & Veitch (2017, 2018). When participants were invited back to complete the retention study, they were asked to complete a series of testing scenarios that challenged their ability to remember safety protocols demonstrated in the initial experiment. Full story boards for each testing scenario can be seen in Appendix B (from Smith & Veitch, 2017, 2018). These scenarios are described briefly below:

- TE1 – Environment testing scenario: This scenario was designed to test the participant's ability to navigate the virtual space. The scenario asked participants to leave their cabin and find their supervisor at their assigned lifeboat station. Participants were then required to return to their cabin using another valid route.
- TA1 – Alarm testing scenario: This scenario starts participants in their cabin just before an alarm sounds. Participants are required to respond to the alarm by collecting their safety equipment and reaching their muster station by using a valid route. At the muster station, the participants must complete the muster procedure and then return to their cabin after the alarm concludes.
- TC1 - Continually assess situation testing scenario: This scenario is designed to interrupt one of the possible routes that the participants can take to their muster station. Participants must respond to the alarm and complete the standard mustering procedure; however, they must listen to the announcements over the PA to select the most effective route.

- TH1 – Hazard test scenario: In this scenario, participants are exposed to potential hazards and changing alarm states. To successfully complete the scenario, participants must understand what a change in alarm means, as well as have the spatial understanding to avoid the hazards placed in the environment.

Each testing scenario was comprised of learning objectives designed to assess the participant's ability to respond safely. Seven primary learning objectives were assessed throughout the simulation. These learning objectives were as follows:

1) LO1: Spatial Awareness – Was the participant able to recognize important markers and navigate the space to the intended location.
2) LO2: Alarm Recognition – Was the participant able to differentiate alarms and respond accordingly.
3) LO3: Most Effective Route Selected – Was the participant able to select a route appropriate for the scenario.
4) LO4: Assess Emergency Situations and Avoid Hazards – If presented with additional information about the environment, was the participant able to respond to potential hazards and select the correct route.
5) LO5: Mustering Procedure – Was the participant able to complete the mustering procedure.
6) LO6: Safe Practices – Did the participant recall environment specific safety protocols (there is no running allowed on the offshore platform, all fire tight doors must be closed).
7) LO7: First Actions and use of Personal Protective Equipment (PPE) – Did the participant know where to find his/her PPE and how to use it.

Many of the learning objectives listed above are binary in nature (i.e. they can be completed correctly or incorrectly). However, some subjective assessment was required for specific learning objectives (such as the response to hazards and routes selected). To ensure consistent evaluation of all participants, a rubric was developed for each scenario, which provided pass/fail criteria for each learning objective. The rubrics used are identical to those generated by Smith & Veitch (2017, 2018) to allow for paired statistical comparison, details regarding rubric development may be found in Smith & Veitch (2017). The learning objectives present in each testing scenario, as well as their point allocation, are listed in Table 2 through Table 5 below.

Table 2: TE1 Tasks and Performance Measures

Learning Objective	**Task**	**Performance Measure**	**Scoring**
LO1 – Spatial Awareness	Identify secondary muster station	Correct Location	25
LO3 – Routes and Mapping	Travel from Cabin to muster station and back	Most effective route (both ways)	15 (to station) +15 (to cabin) =30
LO6 – Safe Practices	Not running/closes fire doors	0% running 0 doors left open	10 (running) +15 (doors) =25
Total Score			80

Table 3: TA1 Tasks and Performance Measures

Learning Objective	**Task**	**Performance Measure**	**Scoring**
LO1 – Spatial Awareness	Identify primary muster station	Correct Location	25
LO2 – Alarm Recognition	Identify correct platform alarm		
LO3 – Routes and Mapping	Cabin to primary muster station and back	Most effective route (both ways)	15 +15 =30

LO5 – Mustering Procedure	Perform T-card procedure	Stay at station during alarm, move t-card to mustered and back	25
LO6 – Safe Practices	Not running/closes fire doors	0% running 0 doors left open	10 (running) +15 (doors) =25
LO7 – First Actions (PPE)	Collected safety gear	Takes grab bag and Immersion suit	10
Total Score			115

Table 4: TC1 Tasks and Performance Measures

Learning Objective	**Task**	**Performance Measure**	**Scoring**
LO1 – Spatial Awareness	Identify primary muster station	Correct location	25
LO2 – Alarm Recognition	Identify correct platform alarm		
LO3 – Routes and Mapping	Cabin to primary muster station and back	Most Effective route selected based on route blockages and additional information: 1) Valid route selected and followed to muster station 2) Valid route selected for return to cabin 3) Effective Re-routing (if required) 4) Avoids encountering a blocked route	15 +15 +10 +10 =50
LO4 – Assess Emergency	Cabin to primary muster station and back while listening to PA to avoid hazards		
LO5 – Mustering Procedure	Perform T-card procedure	Stay at station during alarm, move t-card to mustered and back	25
LO6 – Safe Practices	Not running/closes fire doors	0% running 0 doors left open	10 (running) +15 (doors) =25
LO7 – First Actions (PPE)	Collected safety gear	Takes grab bag and Immersion suit	10
Total Score			135

Table 5: TH1 Tasks and Performance Measures

Learning Objective	**Task**	**Performance Measure**	**Scoring**

LO1 – Spatial Awareness	Identify muster station	Correct location	25
LO2 – Alarm Recognition	Identify correct platform alarm		
LO3 – Routes and Mapping	Cabin to primary muster station and back	Most Effective route selected based on route blockages and additional information: 1) Selects secondary egress route (from start) 2) Re-routes from primary given PA 3) Takes most effective route in event of re-route 4) Re-routes from primary after seeing hazard	50 (See Table 6 for scoring index)
LO4 – Assess Emergency	Cabin to primary muster station and back while listening to PA to avoid hazards		
LO5 – Mustering Procedure	Perform T-card procedure	Stay at station during alarm, move t-card to mustered position	25
LO6 – Safe Practices	Not running/closes fire doors	0% running 0 doors left open	10 (running) +15 (doors) =25
LO7 – First Actions (PPE)	Collected safety gear	Takes grab bag and Immersion suit Puts on Immersion suit	10 +5 =15
Total Score			140

3.3.2: Interpretation of Performance

Learning objectives within each scenario were not strictly binary and required some interpretation to be evaluated consistently. Some actions were directly measurable, which made them simple to score; others required inference. In this case inference is defined as "the assumption that the scenario participant understood that his/her actions would lead to a specific and desired result". The list below provides a detailed description of how each learning objective was interpreted (binary/inferred/both) and if there were deviations in assessment based on the circumstances of each scenario:

- LO1 – Spatial Awareness (inferred)
    - Spatial awareness is only scored independently in scenario TE1, after which it is scored in conjunction with LO2 for the remaining testing scenarios. The indirect measurement of spatial awareness in this experiment is the participants' ability to reach the correct location. Given that alarm interpretation uses the same indirect measure to gauge competency, LO1 was scored in conjunction with LO2 after the test scenario TE1. The participant was assessed to have gained adequate spatial awareness within the scenario if s/he was able to correctly identify where the starboard lifeboat station was located. This learning objective is independent of the route selected as the participant could take a non-specified route to the correct location.
- LO2 – Alarm Recognition (inferred)
    - Throughout the testing scenarios, there were two possible alarm states. The first is the General Platform Alarm (GPA), and the second is the Prepare to Abandon Platform Alarm (PAPA). The GPA indicates that the participant must go to the assigned muster station, while the PAPA indicates that the participant must go to the assigned lifeboat station. While it is impossible to understand how the participant interprets the alarm directly, the observer may infer that the alarm was correctly interpreted if the correct location was reached. This learning objective is independent of route selected.
- LO3 – Routes and Mapping (binary/inferred)

- Routes and mapping assesses the participant's ability to follow designated routes during each scenario. Given the wide variety of ways that a route may be followed, the observer used landmarks to assess if the participant understood the correct route to follow in each scenario. Participants were given half the available score for following the correct route from their cabin to the desired location, and the other half if they used a valid route on their return to their cabin. In the event the participant committed a minor deviation from the route, s/he was given a point deduction, but did not fail the scenario. A minor deviation within this context is defined as "any time the participant demonstrates hesitation in the route to select, which results in deviation from the designated route". In contrast, a major deviation (which would result in a failure of the learning objective) is defined as "any time the participant deviates from the designated route and crosses the threshold of a fire tight door, or a predetermined marker as per the observer's rubric". The difference is demonstrated through the following example: 'After exiting the cabin, a participant follows the secondary egress route. However, before exiting the hallway, the participant changes direction and takes the primary route'. This would be considered a minor deviation as the participant changed his/her route before leaving the immediate area. Had the participant crossed the threshold of a fire tight door, it would have been considered a major deviation resulting in a failure. LO3 was assessed in conjunction with LO4 in testing scenarios TC1 and TH1 as successful re-routing requires knowledge of effective routes.

- LO4 - Assessing Emergency Situations (inferred/binary)
    - LO4 captures effective route selection if one of the viable routes becomes blocked and examines the participant's capacity to respond to changes within the environment. This is best described on a per scenario basis:
        - TC1: During this testing scenario, an announcement states that there is crew working to solve an issue in the main stairwell. To receive full points in the scenario, the participant must take the secondary route from his/her cabin down to the muster station and return to the cabin using a valid route. As the PA announcement detailing the emergency is delayed, it is possible for the participants to cross the threshold of the main stairwell door and still pass the scenario. No points are deducted until the participant crosses the threshold of a door. If they select the primary route, it is considered a minor deviation until the Crew working in the main stairwell becomes visible to the participant. The Crew serves as a visual cue to the participant that the wrong path has been selected. At this point, the participant would fail the scenario, but still be given points for re-routing correctly. No points are awarded for the route to the muster station if the participant interacts with the crew. Given that the participant must have demonstrated route competency in previous scenarios, the value for the return route is 30% of the available total, with the value for the initial route being 70% of the available total.

- TH1: During this scenario, there is a change in alarm status that requires the participant to change his/her response to the emergency. Initially, the participant must respond to the GPA, however it quickly escalates to the PAPA alarm. This scenario has no return route to the cabin, so 100% of the available points are allocated for the correct response to the alarm. Table 6 below describes how the scenario is scored and how the participant may lose points, but still pass the scenario.

Table 6: TH1 LO3 & LO4 Scoring Index Summary

Scenario Scoring Summary		
Select secondary route, complete without deviation	1	Pass
Select primary route, re-route before entering main stairs, re-route to secondary route	1	Pass
Select primary route, enter main stairway but do not proceed past C deck landing, re-route to secondary route	0.85	Pass
Select primary route, enter main stairway and re-route onto B deck, re-route to secondary route	0.7	Pass
Select primary route, reach A/B deck landing, do not see hazard. re-route back to B deck and follow secondary route	0.6	Pass
Select primary route, reach A deck landing, see hazard, re-route back to B deck and follow secondary route	0.5	Fail
Select primary route, reach A deck landing, see hazard, re-route to port and continue to lifeboat station	0.3	Fail
Select primary route, reach A deck landing, see hazard, continue to mess and interact with hazard.	0	Fail

- LO5 - Mustering Procedure (binary)
    - The mustering procedure learning objective aims to determine if the participant has correctly learned the operations required to safely muster in each scenario. The operation includes moving the T-card from the un-mustered section of the board, to the mustered section of the board, then returning it to the un-mustered position at the end of the alarm state. Failure to muster or un-muster results in failure of the learning objective.
- LO6 – Safe Practices (binary)

    - The learning objective regarding safe practices aims to assess the participant's ability to follow general safety protocols that are common in an offshore environment. The first protocol is the policy on running, and the second concerns the use of fire-tight doors. In the context of this environment, running is prohibited while working at the offshore facility. Participants must also remember that fire-tight doors must always remain closed to maintain a positive pressure environment, which stops the spread of fires and smoke. Refraining from running is valued at 40% of the LO6's available points, and correct protocols surrounding doors is allocated the remaining 60%. Running, or leaving a door open will result in failure of a scenario.
- LO7 – First Actions and effective use of Personal Protective Equipment (PPE) (binary)
    - The final learning objective assesses if the participants can locate and effectively use safety equipment in the event of an emergency. If the participants can locate and collect the safety equipment from the cabin at the beginning of a scenario, they are awarded full points in scenarios TA1 and TC1. During scenario TH1, participants are expected to don the immersion suit prior to boarding the lifeboat. For doing this successfully, the participants are awarded additional points. Failure to collect the PPE, or failure to use it when required, results in failure of the scenario.

3.3.3: Retraining scenario selection and the generation of adaptive training matrices

As discussed in Section 3.1.3, adaptive training matrices were developed to ensure that the re-training completed by each participant was consistent based on the mistakes that were made in each testing scenario. This had an additional benefit as it acted as a control, which allowed participant performance to be directly compared on a per scenario basis. By carefully determining the ways in which participants could make errors within the context of the relevant learning objectives, adaptive training matrices avoided potential inconsistencies that could otherwise be introduced by the experimenter. Careful scenario selection also ensured that participants were not exposed to information that could help them be successful in later scenarios. Figures 5 through 8 demonstrate the adaptive training matrices for each testing scenario. A full description of each teaching scenario can be found in Smith & Veitch (2017, 2018).

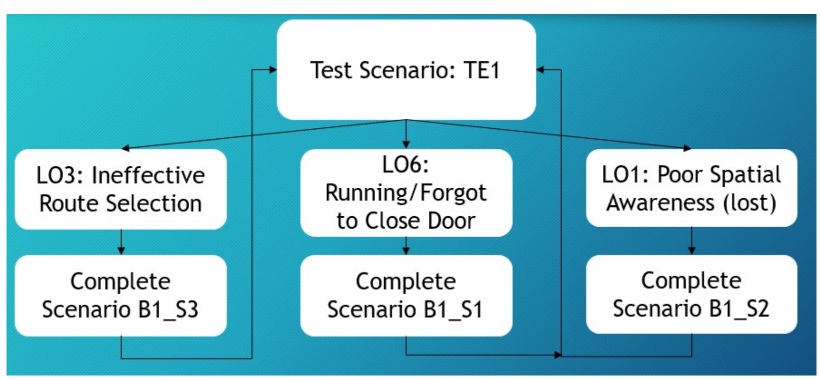

Figure 5: TE1 Adaptive training matrix

Testing scenario TE1 incorporates three learning objectives (LO1, LO3, and LO6), the details of which are discussed in Section 3.4.2. The most fundamental of the learning objectives (LO6) involves offshore safety best practices, which are best addressed through the completion of teaching scenario B1-S1 (block 1, scenario 1). Although this scenario does not interactively explain that running and closing fire doors is a requirement for safe practices through an exercise, it is the focus of the pre-scenario lecture material. If the participants were unable to complete testing scenario TE1 while observing these protocols, they were asked to complete the reading associated with scenario B1-S1, as well as repeat the scenario itself.

If the participants had difficulty following or recalling the correct routes (LO3) within the scenario, a scenario that explicitly demonstrated the two acceptable routes was provided for practice. This scenario was also used if the participants had trouble determining the deck where the muster stations were location. If the participants had trouble with spatial awareness on A deck of the VE (LO1), an exploratory training scenario was provided. This scenario gave participants the opportunity to build a mental map of the area.

Learning objectives LO6 and LO3 were present in every test scenario, while LO1 was only present in test scenario 1 (TE1). The training scenarios selected to address difficulty with LO3 and LO6 remained the same throughout the experiment, regardless of the testing scenario that had been attempted.

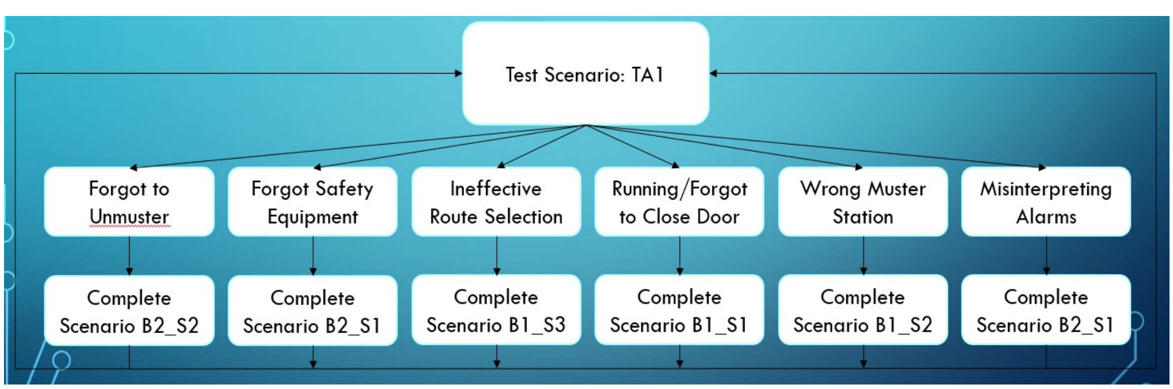

Figure 6: TA1 Adaptive training matrix

Testing scenario TA1 includes new learning objectives that are not explored in TE1, namely LO2: Alarm Interpretation, LO5: Mustering Procedure, and LO7: Correct use of PPE. These new concepts were introduced in the second training block of the SBML study conducted by Smith & Veitch (2017, 2018), and primarily target safe evacuation procedures. This block consisted of two scenarios: one that teaches about alarm recognition, and the second that reviews the mustering procedure in detail. As a result, corrections to mistakes regarding LO2 and LO7 are addressed in the first scenario, and corrections targeting LO5 are reviewed in the second scenario. Errors regarding these learning objectives were addressed with the same training modules for all testing scenarios.

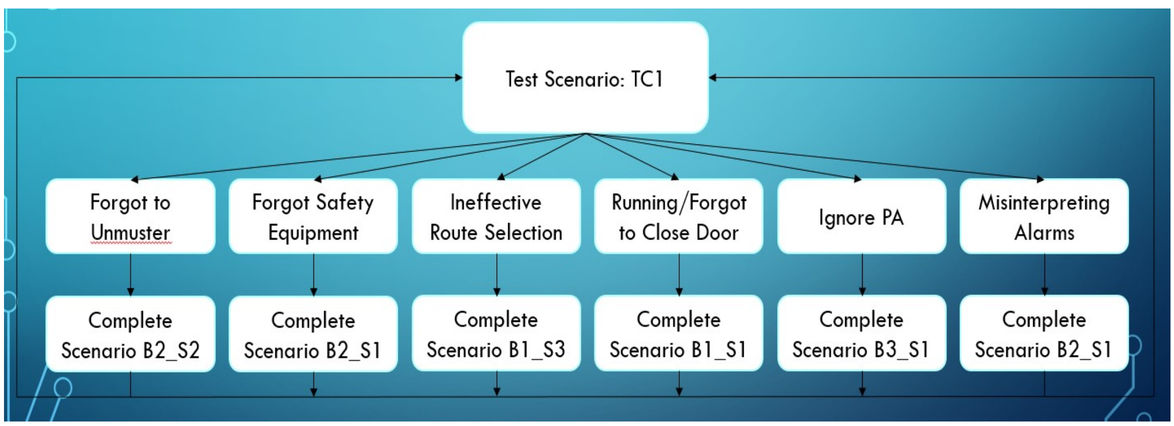

Figure 7: TC1 Adaptive training matrix

Testing scenario TC1 introduces the concept of responding to potentially harmful scenarios (LO4). At this point, routes are assessed as correct only if the participants can identify the most effective route when faced with a potential hazard. Information about the hazard is provided to participants in the form of a PA announcement. If the participants are unable to interpret the information provided and then find the safest route to the muster station, a training scenario was provided. This scenario is from the third block of training scenarios from Smith & Veitch's (2017, 2018) SBML study and offers an opportunity to practice an appropriate response.

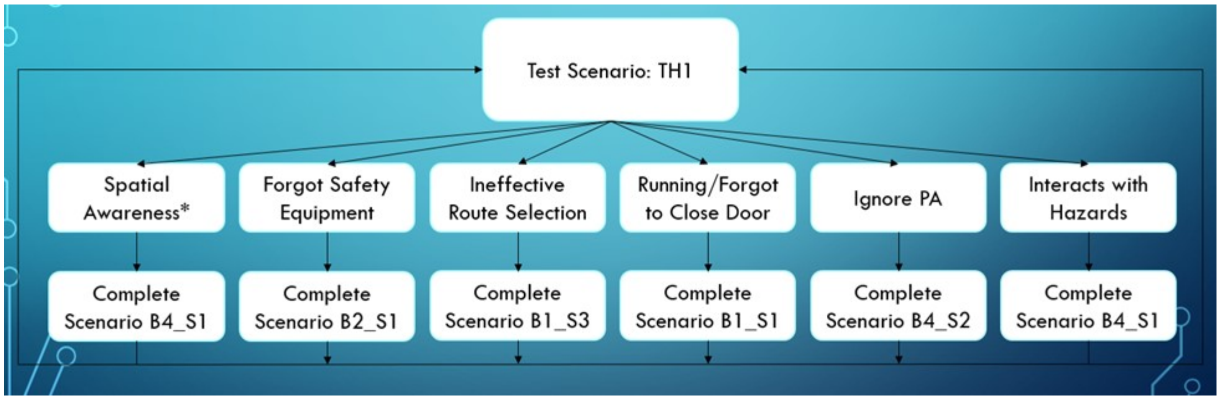

Figure 8: TH1 Adaptive training matrix

The final testing scenario (TH1) changes how the participants must respond to hazards. LO4 is expanded by adding a second PA announcement to the emergency, after which the alarm state changes. This second announcement delivers additional information. The expectation is that the participants will adapt to the changing environment. This testing scenario includes hazards that are harmful to the participants, but are avoidable should the participants correctly respond to the latest information. Avoiding hazards and responding to updated information is captured in the second scenario in the fourth block of training scenarios from the SBML study (Smith & Veitch, 2017, 2018). Finally, this scenario expands on LO7 by asking the participants to use their immersion suit as the emergency escalates. If the participants had issues using their immersion suit, they were asked to complete the first scenario of training block four.

3.4: Data Collection Protocol (Performance Measurements in AVERT)

Data was collected through two methods during the experiment. The first and primary method was through .txt report files. These files were discussed in detail in Section 3.3.2. The AVERT software also generated a replay video file for each scenario attempt. These files were essential in ensuring the accuracy of data collected as they provided a clear demonstration of the participants' actions.

The replay videos acted primarily as a backup to the report files. Throughout each experimental run, the observer made hand written notes of the participant's actions, which included a description of the path the participant took, the decisions that were made, interaction with doors and objects, and a map drawn with an overlay of the path taken. This information provided context for a participant's performance in a scenario, which assisted in consistent score allocation for each learning objective. A sample of the manual reporting templates, as well as a sample report file, is shown in Appendix C.

Chapter 4: Experimental Results

4.1: Measurement of Performance in Retention

4.1.1: Trials to Competence

The results of this thesis are discussed using the data collected from 36 participants who completed the skill retention study after a period of 6 to 9 months. Trials to competence (TTC) is a behavioral measurement technique that originated from the field of applied behavioral analysis. Cooper et al. (2006) define this concept as follows: “A special form of event recording; a measure of the number of responses or practice opportunities needed for a person to achieve a pre-established level of accuracy or proficiency”. In this thesis, trials to competence is used to measure the number of attempts required by each participant to meet the passing criteria for each testing scenario. This measurement was selected as it allows the researcher to infer if the concepts of each testing scenario were retained by the participant and allows for direct comparison to results from Smith & Veitch’s SBML study (2017, 2018).

Table 7 below shows the trials to competence data collected from the participants during the retention experiment. Shaded sections of the table represent data points that have been altered or nullified. Rationale for exclusion and reduction of data points is reported in Section 4.3.

Table 7: Retention Experiment Trials to Competence

TE1		TA1		TC1		TH1		Completion Dates		Delta Months
R	Attempts	P#	Attempts	P#	Attempts	P#	Attempts	Mastery	Retention	
A02	2	A02	2	A02	2	A02	1	15-May-16	18-Jan-17	8
A03	2	A03	2	A03	1	A03	Null	02-Apr-16	27-Dec-16	8
A04	2	A04	2	A04	1	A04	1	09-May-16	31-Jan-17	8
A06	3	A06	2	A06	1	A06	1	19-Apr-16	19-Jan-17	9
A09	Null	A09	Null	A09	Null	A09	Null	06-Apr-16	21-Feb-17	Null
A10	1	A10	2	A10	1	A10	1	10-Apr-16	15-Jan-17	9
A15	2	A15	1	A15	2	A15	Null	10-May-16	29-Dec-16	7
A16	3	A16	2	A16	1	A16	1	25-Apr-16	4-Jan-17	8
A18	1	A18	Null	A18	1	A18	1	02-May-16	6-Jan-17	8
A19	2	A19	2	A19	2	A19	1	11-May-16	10-Feb-17	8
A21	1	A21	1	A21	1	A21	2	12-May-16	12-Jan-17	8
A24	Null	A24	2	A24	1	A24	1	26-May-16	5-Jan-17	7
A26	2	A26	2	A26	1	A26	1	31-May-16	5-Jan-17	7
A30	2	A30	2	A30	1	A30	1	04-Jun-16	2-Feb-17	7
A31	2	A31	2	A31	2	A31	2	08-Jun-16	1-Mar-17	8
A32	2	A32	1	A32	1	A32	1	16-Jun-16	13-Jan-17	6
A34	1	A34	2	A34	1	A34	2	28-Jun-16	22-Jan-17	6
A35	2	A35	1	A35	1	A35	1	14-Jun-16	22-Dec-16	6
A37	2	A37	2	A37	1	A37	1	20-Jun-16	26-Jan-17	7
A38	1	A38	1	A38	1	A38	1	20-Jun-16	27-Dec-16	6
A40	2	A40	2	A40	1	A40	1	16-Jun-16	11-Feb-17	7
A41	2	A41	2	A41	1	A41	1	15-Jun-16	13-Feb-17	7
A42	1	A42	1	A42	1	A42	1	11-Jul-16	10-Feb-17	6
A44	2	A44	1	A44	1	A44	1	23-Jun-16	23-Jan-17	7
A45	2	A45	2	A45	1	A45	1	22-Jun-16	10-Feb-17	7
A46	2	A46	1	A46	1	A46	1	24-Jun-16	27-Jan-17	7
A47	2	A47	1	A47	1	A47	Null	11-Jul-16	14-Mar-17	8
A48	1	A48	3	A48	1	A48	1	14-Jul-16	1-Feb-17	6
A49	2	A49	2	A49	1	A49	1	19-Jul-16	13-Feb-17	6
A50	1	A50	1	A50	1	A50	1	22-Jul-16	23-Jan-17	6
A51	1	A51	1	A51	1	A51	1	21-Jul-16	6-Mar-17	7
A52	1	A52	2	A52	1	A52	1	22-Jul-16	24-Mar-17	8
A53	1	A53	2	A53	2	A53	1	25-Jul-16	26-Feb-17	7
A56	2	A56	1	A56	1	A56	1	30-Jul-16	12-Mar-17	7
A59	2	A59	2	A59	1	A59	1	01-Aug-16	20-Mar-17	7
A60	2	A60	1	A60	1	A60	1	02-Aug-16	3-Mar-17	7
A61	2	A61	2	A61	1	A61	1	06-Aug-16	25-Feb-17	6
A62	Null	A62	Null	A62	Null	A62	Null	07-Aug-16	16-Dec-16	Null

The average retention interval for this experiment was 7.13 months with a standard deviation of 1.09 months, demonstrating that most participant data was captured during the intended retention interval. Trials to competence can provide an understanding of participant competency for each testing scenario. Table 8 below shows the average number of attempts required in each scenario, the standard deviation, and the number of participants who required multiple attempts. Table 9 presents the participant success rate in each testing scenario per number of attempts.

Table 8: Trials to Competence Data Summary

Scenario	TE1	TA1	TC1	TH1
Average # of Attempts	1.743	1.657	1.139	1.091
Standard Deviation	0.561	0.539	0.351	0.292
# of Participants w/ 1 Attempt	11	13	31	30
# of Participants w/ 2 Attempts	22	21	5	3
# of Participants w/ 3 Attempts	2	1	0	0
Total Number of Participants	35	35	36	33

Table 9: Scenario success rate per number of attempts

Scenario	#	1st Attempt	2nd Attempt	3rd Attempt
TE1R	35	30.56%	94.44%	100.00%
TA1R	35	36.11%	97.22%	100.00%
TC1R	36	86.11%	100.00%	N/A
TH1R	33	90.91%	100.00%	N/A

Most participants required more than one attempt in the early testing scenarios TE1 and TA1. This is interesting when compared to the results of scenarios TC1 and TH1. TE1 and TA1 are scenarios where six of the seven learning objectives are reintroduced for the first time, the final learning objective (LO4) is re-introduced in TC1. The earlier scenarios (TE1 and TA1) required on average more attempts and had a higher standard deviation. This demonstrates that the participants had the greatest difficulty when asked to recall learning objectives for the first time. This observation will be informed by the results reported in 4.1.3: Performance Across Learning Objectives.

4.1.2: Test Scenario Performance Scores

In this thesis, participant performance score was tracked on a per scenario basis, where points were awarded for successfully completing the learning objectives as described in Section 3.3.2. The performance scores calculated for each participant can be examined in aggregate and categorized based on the number of attempts. In Table 10 and Table 11 below, a summary of the performance data is presented based on the participants' first and second attempts in each scenario, where average refers to the average number of points achieved in the scenario across all participants. Few participants required three attempts to complete any testing scenario (two participants in scenario TE1 and one participant in scenario TA1), and three attempts was the maximum number of attempts required by any participant. As a result, insufficient data is available to populate a summary table providing an overview of third attempt performance. It is important to note that Table 10 contains the entire sample, while Table 11 contains only the participants that required a second scenario attempt. The full summary of performance for each participant categorized by number of attempts may be seen in Doody & Veitch (2017), which includes all the data collected during the retention experiment.

Table 10: Summary Performance Data (First Attempt)

First Attempt Performance Data Retention							
TE1		TA1		TC1		TH1	
Average	0.722	*Average*	0.837	*Average*	0.956	*Average*	0.954
Standard Deviation	0.269	*Standard Deviation*	0.182	*Standard Deviation*	0.087	*Standard Deviation*	0.137
Count	35	*Count*	35	*Count*	36	*Count*	33
Confidence Coefficient (0.95)	1.960	*Confidence Coefficient (0.95)*	1.960	*Confidence Coefficient (0.95)*	1.960	*Confidence Coefficient (0.95)*	1.960
Margin of Error	0.045	*Margin of Error*	0.031	*Margin of Error*	0.015	*Margin of Error*	0.024
Upper Bound	0.768	*Upper Bound*	0.868	*Upper Bound*	0.971	*Upper Bound*	0.978
Lower Bound	0.677	*Lower Bound*	0.807	*Lower Bound*	0.942	*Lower Bound*	0.930
Max	1	*Max*	1	*Max*	1	*Max*	1
Min	0.09	*Min*	0.35	*Min*	0.63	*Min*	0.29
Range	0.91	*Range*	0.65	*Range*	0.37	*Range*	0.71

Table 11: Summary Performance Data (Second Attempt)

Second Attempt Performance Data							
TE1		TA1		TC1		TH1	
Average	0.980	*Average*	0.990	*Average*	1	*Average*	1.000
Standard Deviation	0.068	*Standard Deviation*	0.046	*Standard Deviation*	0	*Standard Deviation*	0.000
Count	24	*Count*	22	*Count*	5	*Count*	3
Confidence	1.960	*Confidence*	1.960	*Confidence*	1.96	*Confidence*	1.960
Margin of Error	0.014	*Margin of Error*	0.010	*Margin of Error*	0	*Margin of Error*	0.000
Upper Bound	0.994	*Upper Bound*	1.000	*Upper Bound*	1	*Upper Bound*	1
Lower Bound	0.967	*Lower Bound*	0.980	*Lower Bound*	1	*Lower Bound*	1.000
Max	1	*Max*	1	*Max*	1	*Max*	1
Min	0.72	*Min*	0.78	*Min*	1	*Min*	1.000
Range	0.28	*Range*	0.22	*Range*	0	*Range*	0.000

As indicated by the trials to competence metric, participants achieved lower average performance in testing scenarios TE1 and TA1 on the first attempt. Performance in these scenarios varied greatly with the lowest scores being 9% and 35% for TE1 and TA1, respectively. This observation leads to the conclusion that participants did not remain at the post training levels attained during Smith & Veitch's (2017, 2018) SBML study over a period of 6 to 9 months. It does not provide insight into which learning objectives deteriorate over time.

The average performance score throughout all testing scenarios during the second attempt was greater than 95%, and the standard deviation was greatly reduced. These results indicate that it is possible to retrain to competence quickly through use of targeted training modules, and that exposure to the environment can improve performance in more difficult scenarios.

4.1.3: Performance Across Learning Objectives

The data presented in this section shows the performance of participants for each learning objective. The performance of participants is demonstrated through first and second attempt performance scores.

LO1 & LO2: Spatial Awareness & Alarm Recognition

Both learning objectives LO1 and LO2 were measured indirectly through the participant arriving at the "correct location" in each testing scenario. Given that these learning objectives were both measured through reaching the "correct location", they have been reported together. Reaching the correct location in each testing scenario awarded participants with 25 points of the total available for the scenario. Although this learning objective was scored in a binary pass/fail, the average performance score across all scenario attempts was also recorded. The tables presented below (Table 12 through Table 23) show the average performance score on each scenario attempt, standard deviation, point average, and the number of participants to pass the scenario. The "number of participants to pass" represents the number of participants who were successful in the scenario attempt.

Table 12: LO1 & LO2 First Attempt Performance

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	80.00%	91.43%	97.22%	96.97%
Standard Deviation	10.15	7.10	4.17	4.35
Point Average	20.00	22.86	24.31	24.24
# of Participants to Pass	28	32	35	32

Table 13: LO1 & LO2 Second Attempt Performance

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	100.00%	100.00%	100.00%	100.00%
Standard Deviation	0	0	N/A	N/A
Point Average	25	25	25	25
# of Participants to Pass	7	3	1	1

A summary of first attempt performance, shown in Table 12, indicates that initial retention of platform layout was strong, where 29 out of 35 participants were able to reach the assigned location on the first attempt in TE1. After the initial testing scenario, participant performance increased significantly with scores greater than 90% in all other scenarios. Second attempt performance shows (see Table 13) that all participants were able to reach the correct location after receiving targeted re-training.

LO3 & LO4: Routes and Mapping & Assessing Emergency Situations

LO3 and LO4 both measured the participant's ability to select the correct evacuation route based on the scenario requirements. Scenarios TE1 and TA1 strictly evaluated the route taken, and for this reason route deviations often resulted in a failure of the scenario. Route selection became a dynamic task in scenarios TC1 and TH1 as additional information was introduced as the scenario progressed. Thus, TC1 and TH1 were scored with more flexibility regarding route deviation. The full description of how route selection was scored may be seen in Section 3.4.2. A summary of results for LO3 & LO4 first and second attempt performance may be seen in Table 14 and Table 15 respectively.

Table 14: LO3 & LO4 First Attempt Performance

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	62.14%	97.14%	90.97%	92.58%
Standard Deviation	10.97	3.53	9.04	12.14
Point Average	18.64	29.14	45.49	46.29
# of Participants to Pass	16	33	33	31

Table 15: LO3 & LO4 Second Attempt Performance

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	93.42%	100.00%	100.00%	100.00%
Standard Deviation	6.04	0.00	0.00	0.00
Point Average	28.03	30.00	50.00	50.00
# of Participants to Pass	17	2	3	2

As noted above, participants demonstrated a strong capacity to locate the correct location in LO1 and LO2. However, the performance in LO3 and LO4 demonstrates that participants were unable to take the correct route reliably to the desired location. First attempt performance in scenario TE1 demonstrates that participants had an average performance score of 62.14% (with a standard deviation of 10.97) in following the desired route to the lifeboat station and then back to the cabin. Second attempt performance in this scenario resulted in a much higher average score of 93.42% (with a standard deviation of 6.04). Only two participants required a third attempt to complete this scenario, after which the success rate reached 100%.

After scenario TE1, average performance in route selection increased to 97.14% for TA1. However, a drop in performance was observed when hazard response was introduced in scenarios TC1 and TH1. The average performance in TC1 and TH1 dropped to 90.97% and 92.58% respectively, with standard deviations of 9.04 and 12.14. This drop may have been due to the increase in difficulty presented by these scenarios. In both TC1 and TH1, only three participants were not successful in their first attempt, all of whom were able to complete the scenario successfully in the second attempt.

LO5: Mustering Procedure

LO5 measured the participants' ability to correctly complete the muster procedure during an emergency response scenario. Participants were required to move their T-card after arriving at the muster station and return it to the original position after the emergency drill had concluded. The muster procedure was not included in scenario TE1; it was first tested in TA1. Only the initial movement of the T-card was required in scenario TH1. A summary of results for LO5 first and second attempt performance may be seen in Table 16 and Table 17, respectively.

Table 16: LO5 First Attempt Performance

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	N/A	60.00%	97.22%	96.97%
Standard Deviation	N/A	12.43	4.17	4.35
Point Average	N/A	15	24	24
# of Participants to Pass	N/A	21	35	32

Table 17: LO5 Second Attempt Performance

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	N/A	100.00%	100.00%	100.00%
Standard Deviation	N/A	0.00	N/A	N/A
Point Average	N/A	25	25	25
# of Participants to Pass	N/A	14	1	1

Participants had difficulty recalling the full mustering procedure during the first attempt of scenario TA1, resulting in an average performance score of 60% (with a standard deviation of 12.43). Participant performance improved on the second attempt to 100%. After initial re-exposure to the mustering procedure, participant performance increased to 97.22% (with a standard deviation of 4.17) for TC1, and 96.97% (with a standard deviation of 4.) for TH1. In both TC1 and TH1, only one participant required a second attempt due to inability to complete the muster procedure correctly.

LO6: Safe Practices

LO6 had two criteria required for success: completing the scenarios without running and ensuring that all fire tight doors were closed. First and second attempt performance for both criteria can be seen in Table 18 through Table 21 below.

Table 18: LO6 First Attempt Performance (Running)

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	60.00%	100.00%	100.00%	100.00%
Standard Deviation	4.97	0.00	0.00	0.00
Point Average	6.39	10.00	10.00	10.00
# of Participants to Pass	21	35	36	33

Table 19: LO6 Second Attempt Performance (Running)

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	100.00%	N/A	N/A	N/A
Standard Deviation	0	N/A	N/A	N/A
Point Average	10	N/A	N/A	N/A
# of Participants to Pass	14	N/A	N/A	N/A

Table 20: LO6 First Attempt Performance (Closing Doors)

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	86.11%	94.29%	100.00%	100.00%
Standard Deviation	5.33	3.53	0.00	0.00
Point Average	12.86	14.14	15.00	15.00
# of Participants to Pass	30	33	36	33

Table 21: LO6 Second Attempt Performance (Closing Doors)

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	100.00%	100.00%	N/A	N/A
Standard Deviation	0	0	N/A	N/A
Point Average	15	15	N/A	N/A
# of Participants to Pass	5	2	N/A	N/A

The first attempt performance for running on the platform in TE1 demonstrates that many participants forgot that running was prohibited. This resulted in a first attempt performance average of 60% in testing scenario TE1. After initially making the mistake, participants did not run on the platform again. Second attempt performance for TE1 increased to 100% and remained at 100% for the following first attempts.

Participant performance with regards to fire tight doors was high in all scenarios. The first attempt average performance score in TE1 was 86.11% (standard deviation 5.33), rising to 94.29% in TA1 (standard deviation 3.53), and reaching 100% for TC1 and TH1. Second attempt performance across all required scenario re-attempts reached an average performance score of 100%.

LO7: First Actions and Effective use of PPE

LO7 required the correct use of PPE. In the event of an emergency, participants were required to collect their PPE and use it appropriately. First and second attempt performance for both criteria can be seen in Table 22 and Table 23 below.

Table 22: First Attempt Performance (Use of PPE)

Attempt 1	TE1	TA1	TC1	TH1
Average Performance %	N/A	51.43%	100.00%	93.94%
Standard Deviation	N/A	5.07	0.00	2.92
Point Average	N/A	5.14	10.00	14.03
# of Participants to Pass	N/A	18	36	32

Table 23: Second Attempt Performance (Use of PPE)

Attempt 2	TE1	TA1	TC1	TH1
Average Performance %	N/A	100.00%	N/A	100.00%
Standard Deviation	N/A	0	N/A	N/A
Point Average	N/A	10	N/A	15
# of Participants to Pass	N/A	17	N/A	1

First attempt performance in scenario TA1 was low. 51.43% of participants forgot to collect the required PPE from their cabin during the first attempt of scenario TA1. After this initial mistake, second attempt performance in TA1 went to 100%. This trend of 100% continued through TC1 and only dropped off in TH1 when additional steps were added to the safe response procedure. Performance in TH1 dropped to an 93.94% success rate, with second attempt performance again reaching 100%.

The second criteria introduced in scenario TH1 required participants to put on their immersion suits at the starboard lifeboat station. Scoring of this learning objective was relaxed as a glitch was identified in the software used for this experiment, which affected some participants' ability to put on the immersion suit. An invisible box was present on the deck of the platform near where the backup safety equipment was stored, which prohibited participants from using the immersion suit. Participants who attempted to put on the suit but were unable were awarded full score. If the participant was able to put on their immersion suit at all, they passed the scenario. However, they were not awarded the points for putting on the suit if they attempted to collect an immersion suit from the back-up supply cabinets more than once. Attempting to collect the immersion suit several times demonstrates that the participant does not understand the contents of the safety equipment bag, which was collected when they left their cabin.

4.1.4: Temporally Grouped Performance

Performance in the retention study was also examined along the time axis to determine if a specific time frame within the retention interval exhibited decreased performance. Participants were sorted into groups based on the number of months between Smith & Veitch's (2017, 2018) SBML experiment and the retention experiment. This resulted in four groups ranging from 6 months to 9 months. The mean and standard deviation of each group was calculated based on the aggregated first attempt performance scores, the results of which are presented in Table 24. There is no discernable trend in the results of TE1, TC1, and TH1 over the monthly intervals. Average performance scores in testing scenario TA1 decline monotonically from month 6 to month 9 of the retention interval. In aggregate, the results appear to be insensitive to the month in which the participant was tested.

Table 24: Grouped Performance Score Summary

6 months				
P#	TE1	TA1	TC1	TH1
Average	0.83	0.93	0.97	0.95
Std. Dev.	0.24	0.11	0.07	0.12
N	9.00	9.00	9.00	9.00

7 months				
P#	TE1	TA1	TC1	TH1
Average	0.63	0.90	0.96	0.99
Std. Dev.	0.28	0.11	0.10	0.02
N	14.00	15.00	15.00	14.00

8 months				
P#	TE1	TA1	TC1	TH1
Average	0.77	0.70	0.94	0.90
Std. Dev.	0.27	0.22	0.09	0.25
N	10.00	9.00	10.00	8.00

9 months				
P#	TE1	TA1	TC1	TH1
Average	0.70	0.59	1.00	0.98
Std. Dev.	0.29	0.15	0.00	0.03
N	2.00	2.00	2.00	2.00

4.1.5: Participants Demonstrating Difficulty in Retention

To determine if any participants exhibited higher difficulty in recalling the learning objectives from Smith & Veitch's (2017, 2017) SBML experiment, an analysis of each learning objective was conducted to determine if participants were unsuccessful in the same learning objective more than once. The result of this analysis can be seen in Table 25.

Table 25: Participants who were unsuccessful in the same learning objective more than once

Learning Objective	Participant #
LO1 & LO2	N/A
LO3 & LO4	A19, A31, A32, A41
LO5	N/A
LO6 - Running	None
LO6 - Doors	A19
LO7 - PPE	A30, A31

Table 25 shows that participants had the most difficultly with effective route selection, closing fire tight doors, and the effective use of PPE. Participants had the most difficulty with route selection and hazard response, as 4/36 participants failed to complete this learning objective correctly after corrective training. There were eight instances where the same learning objective was failed more than once by the same participant. The eight failures (or repetitions) were completed by six participants, meaning two participants encountered elevated levels of difficulty in recalling more than one learning objective despite the retraining provided.

Most participants who returned to complete the retention experiment were successful on the first attempt in at least two testing scenarios. However, there were three participants who demonstrated increased difficulty with their first attempts: participants A02, A19, and A31. Participants A02 and A19 were successful in only one of their first attempts across all testing scenarios, and participant A31's first attempt was unsuccessful in all testing scenarios. Two of these participants also had difficulty completing multiple learning objectives after being retrained. Participants A02, A19, and A31 have a commonality as they all completed the retention experiment towards the end of the acceptable retention interval. All three participants were absent from the training environment for a period of 8 months.

4.2: Scoring Comparison (Mastery versus Retention)

To make the data collected by Smith & Veitch (2017, 2018) directly comparable to the data collected for this thesis, Smith & Veitch's (2017, 2018) dataset was reduced from the original 55 participants to include only participants who completed both studies. This ensured that the same sample would be compared between both experiments. To further ensure statistical validity, scoring procedures between experiments were kept consistent to ensure precision and comparability. All data points that could not be reliably applied to the scoring rubric were excluded from the analysis and are described in section 4.3.

4.2.1: Trials to Competence

To illustrate the differences between the SBML study (Smith & Veitch, 2017, 2018) and the retention study presented in this thesis, the trials to competence were compared. The trials to competence (or number of required attempts to success) for each scenario from Smith & Veitch's (2017, 2018) study are summarized in Table 26, which is directly comparable to the data presented in Section 4.1 Table 8.

Table 26: Trials to Competence (SBML)

Scenario Code	TE1	TA1	TC1	TH1
Average # of Attempts	1.229	1.229	1.167	1.212
Standard Deviation	0.547	0.426	0.378	0.415
# of Participants w/ 1 Attempt	29	27	30	27
# of Participants w/ 2 Attempts	4	8	6	6
# of Participants w/ 3 Attempts	2	0	0	0
Total Number of Participants	35	35	36	33

Figure 9 below shows the average first attempt success rate for participants in both studies. The data from Smith & Veitch's (2017, 2018) study is represented by the patterned bars; and the retention data is represented by the solid bars. The comparison in Figure 9 shows that first attempt performance in the retention study for scenarios TE1 and TA1 was significantly lower than performance in its SBML counterpart. The first attempt pass rate in Smith & Veitch's experiment (2017, 2018) across all scenarios is high, while the passing rate for the first attempt in the retention study is low (with a difference in excess of 40%). The notable drop in the first attempt success rate for scenarios TE1 and TA1 of the retention study shows that there is clear skill fade over the retention interval.

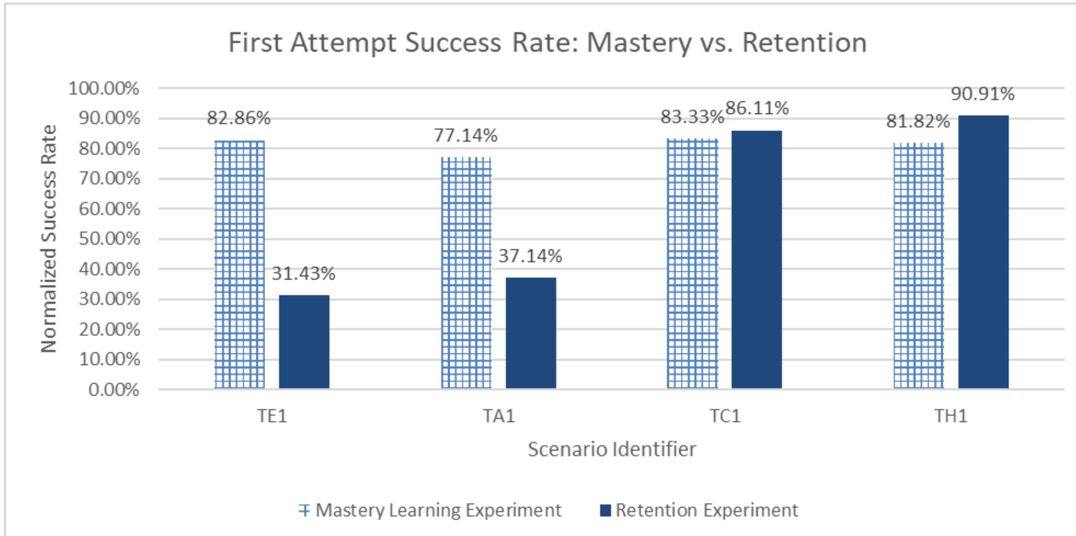

Figure 9: First Attempt Success Rate: SBML versus Retention

Figures 10 through 13 provide a more detailed comparison of the trials to competence in both experiments, showing the number of required attempts for each scenario cumulatively. Figure 10 shows the cumulative results for testing scenario TE1, where all participants in both experiments were able to successfully complete the scenario in a maximum of three attempts. The performance discrepancy noted above in first attempt performance between both experiments is more clearly illustrated here with 29/35 participants completing the scenario successfully in the SBML experiment, and only 11/35 participants completing it successfully in the retention experiment. The success rate for second attempt performance in the retention study improves drastically and matches the SBML experiment with 33/35 successful participants, with all participants completing the scenario successfully on the third attempt for both experiments.

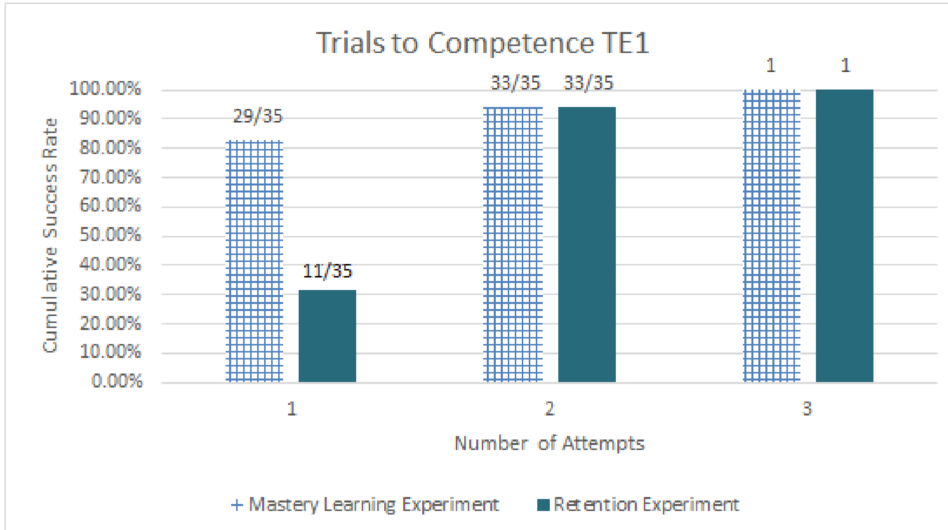

Figure 10: TE1 SBML/Retention Trials to competence comparison

Figure 11 shows the cumulative results for testing scenario TA1 and shows comparable results to those shown in testing scenario TE1. The performance discrepancy between the two experiments is clear with 27/35 successful participants on the first attempt in the SBML experiment and 13/35 successful participants in the retention experiment. Improved performance for the second attempt in the retention experiment is also noted with 34/35 participants being successful, and a single participant requiring a third attempt.

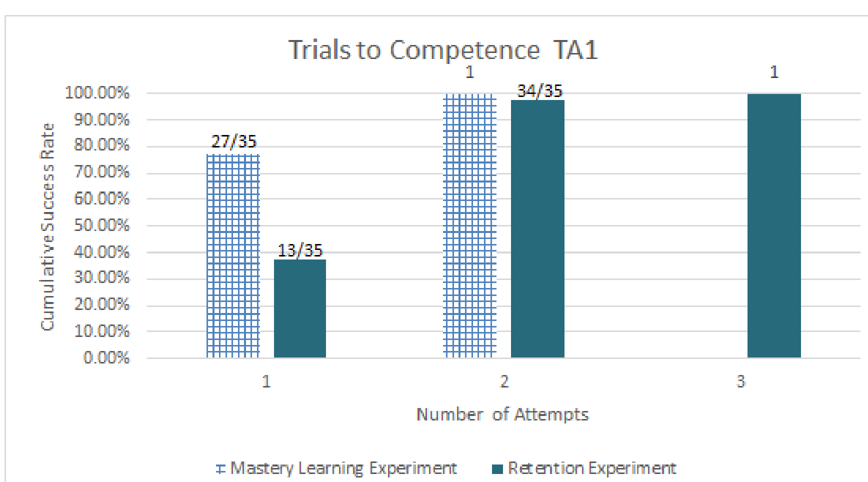

Figure 11: TA1 SBML/Retention Trials to competence comparison

Figures 12 and 13 show that first attempt performance in the retention experiment exceeded the first attempt performance in the SBML experiment, in contrast to TE1 and TA1 results. All participants in TC1 and TH1 demonstrated competency by the second scenario attempt. This is an interesting observation because test scenarios TC1 and TH1 are more complex than TE1 and TA1, and performance was consistently lower for the earlier scenarios in the retention experiment.

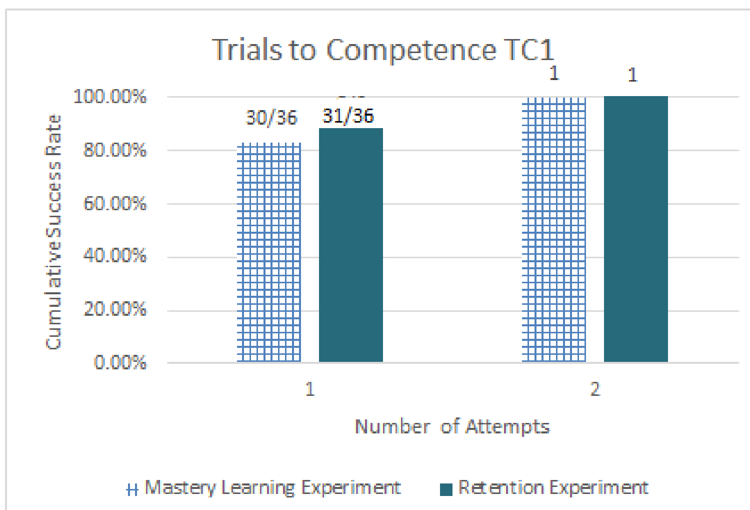

Figure 12: TC1 SBML/Retention Trials to competence comparison

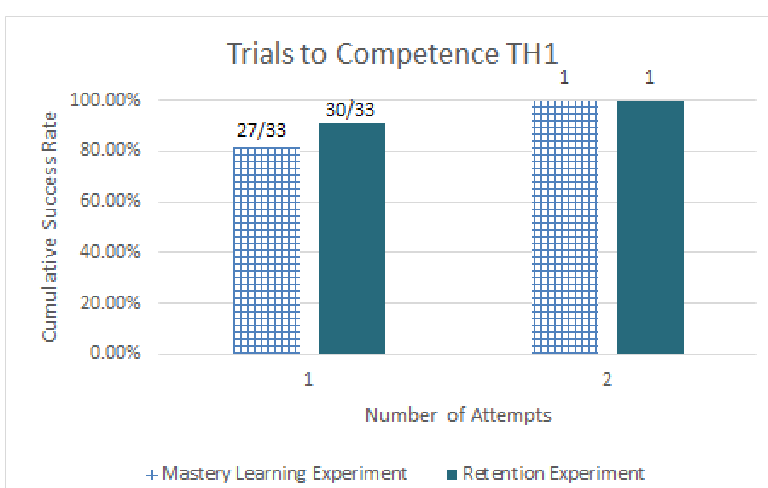

Figure 13: TH1 SBML/Retention Trials to competence comparison

4.2.2: Statistical Comparison of SBML to First Attempt Retention Scores

The results presented in Section 4.2.1: Trials to Competence demonstrate that there was a clear difference in performance between studies. To determine the significance of the data collected in the retention experiment, comparisons were made to the data collected in the SBML study conducted by Smith & Veitch (2017, 2018). To determine if the number of attempts taken during the SBML experiment differed from the number of trials required in the retention experiment, a Pearson chi-square test was conducted. To evaluate the effects of the retention interval on performance, the overall score on the successful (final) attempt in the SBML experiment was compared to the first attempt performance in the retention experiment for each scenario. The results were then investigated further by examining each learning objective to determine where the skill fade was most prominent.

To determine the normalcy of each dataset a Shapiro-Wilkes test was conducted on all performance metrics, the result of which determined that none of the collected data followed a normal distribution. To assess the data, a non-parametric Wilcoxon Signed Rank Test was conducted for each comparison to verify the statistical significance of the findings. A basic Sign test was also conducted to verify the result. In the event the results of the tests conflicted, the histogram of the distribution was examined. If the distribution was found to be symmetric about the median, then the results of the Wilcoxon Signed Rank test took precedent; in the event the distribution was non-symmetric, the result of the Sign test took precedent.

4.2.2.1: Trials to Competence (Pearson Chi Square test)

To conduct the Pearson chi square test, the number of attempts taken in each experiment was recorded in a table. This table showed the number of attempts taken by all participants in each scenario across both studies. The observed values allowed for an expected result table to be generated. Finally, both tables were used to develop a contingency table and calculate the chi-square value. The chi square value generated for each scenario was then compared to chi square distribution for the relevant degrees of freedom and significance level (i.e. 5%). For the null hypothesis to pass, the following inequality must be satisfied:

- chi square value < distribution value.

In this experiment the hypothesis is stated mathematically in Section 1.3, and is re-iterated as follows:

- Null Hypothesis: The number of attempts taken in the SBML study will be the same as number of attempts taken in the retention study.
- Alternative Hypothesis: The number of attempts taken in the SBML study will be different from the number of attempts taken in the retention study.

The results from testing scenario TE1 can be seen in Table 27. Given that participants required up to three attempts to be successful in both experiments, the degrees of freedom for the comparison was determined to be 2. At a significance level of 0.05 with two degrees of freedom, the chi square distribution yielded a value of 5.99 while the test statistic was determined to be 21.46. As a result, the null hypothesis is rejected which shows that there is a clear difference between the repeated measures for testing scenario TE1.

Table 27: TE1 Chi Square Summary

	TE1 - Observed		
	Mastery	**Retention**	**Total**
1 Attempt	29	11	40
2 Attempts	4	23	27
3 Attempts	2	2	4
Total	35	36	71

TE1 - Expected		
	Mastery	**Retention**
1 Attempt	19.718	20.282
2 Attempts	13.310	13.690
3 Attempts	1.972	2.028

Contingency Table				
Observed	Expected	(O-E)	(O-E)^2	((O-E)^2)/E
29	19.718	9.282	86.150	4.369
11	20.282	-9.282	86.150	4.248
4	13.310	-9.310	86.673	6.512
23	13.690	9.310	86.673	6.331
2	1.972	0.028	0.001	0.000
2	2.028	-0.028	0.001	0.000
Chi-Square Value--->				21.461

The results for scenario TA1 are shown in Table 28. The chi square test was conducted at the same significance level and degrees of freedom as TE1. The chi square value generated in the contingency table was approximately 12.42, which is greater than the value generated by the chi square distribution. The null hypothesis is again rejected, demonstrating that there is a difference in the repeated measures for this testing scenario.

Table 28: TA1 Chi Square Summary

	Alarms - Observed		
	Mastery	Retention	Total
1 Attempt	27	13	40
2 Attempts	8	22	30
3 Attempts	0	1	1
Total	35	36	71

Alarms - Expected		
	Mastery	Retention
1 Attempt	19.718	20.282
2 Attempts	14.789	15.211
3 Attempts	0.493	0.507

Contingency Table				
Observed	Expected	(O-E)	(O-E)^2	((O-E)^2)/E
27	19.718	7.282	53.023	2.689
13	20.282	-7.282	53.023	2.614
8	14.789	-6.789	46.087	3.116
22	15.211	6.789	46.087	3.030
0	0.493	-0.493	0.243	0.493
1	0.507	0.493	0.243	0.479
Chi-Square Value--->				12.422

The results calculated for scenarios TC1 and TH1 can be seen in Table 29 and Table 30, respectively. These tests differ from TE1 and TA1 as they did not have any participants who required a third attempt in either experiment. As a result, the chi square test for TC1 and TH1 had one degree of freedom. At a significance level of 0.05, the chi square distribution yielded a value of 3.84. Scenario TC1 generated a chi square value of 0.122, and scenario TH1 generated a chi square value of 0.753. In both cases the chi square value is lower than 3.84 (the expected value from the chi-square distribution) and so the null hypothesis must be accepted. This result shows that there is no observable difference between the repeated measures for testing scenario TC1 or TH1.

Table 29: TC1 Chi Square Summary

	Assess - Observed		
	Mastery	Retention	Total
1 Attempt	30	31	61
2 Attempts	6	5	11
Total	36	36	72

Assess - Expected		
	Mastery	Retention
1 Attempt	30.070	30.930
2 Attempts	5.423	5.577

Contingency Table				
Observed	Expected	(O-E)	(O-E)^2	((O-E)^2)/E
30	30.070	-0.070	0.005	0.000
31	30.930	0.070	0.005	0.000
6	5.423	0.577	0.333	0.061
5	5.577	-0.577	0.333	0.060
Chi-Square Value--->				0.122

Table 30: TH1 Chi Square Summary

	Hazard - Observed		
	Mastery	Retention	Total
1 Attempt	27	32	59
2 Attempts	6	4	10
Total	33	36	69

Hazard - Expected		
	Mastery	Retention
1 Attempt	29.085	29.915
2 Attempts	4.930	5.070

Contingency Table				
Observed	Expected	(O-E)	(O-E)^2	((O-E)^2)/E
27	29.085	-2.085	4.345	0.149
32	29.915	2.085	4.345	0.145
6	4.930	1.070	1.146	0.232
4	5.070	-1.070	1.146	0.226
Chi-Square Value--->				0.753

The results of the Pearson Chi-Square tests indicate there was an observable difference in trials to competence only in testing scenarios TE1 and TA1. Demonstrated dependence does not provide a direct explanation of why the result occurred. However, dependence could be interpreted as an indication that participants who had a great deal of difficulty in being successful in Smith & Veitch's (2017, 2018) experiment had better results in the retention experiment. This could indicate that the additional practice that some participants received because of the difficulty they had in the SBML experiment, correlates with a higher level of retention of longer intervals. This concept is known as the contextual interference effect which is a well documented effect in motor-learning literature. Further details regarding this effect may be reviewed in the meta analysis conducted by Brady (2004). The result that there was no observable difference in trials to competence for scenarios TC1 and TH1 is also interesting. This result could indicate that participants rapidly returned to competency in the retention experiment, which lead to an increased first attempt pass rate in the latter test scenarios.

4.2.2.2: Aggregated Performance

To examine the impact that the retention interval had on participant performance in the retention study, the aggregated performance score for each testing scenario was populated for both experiments. To most effectively demonstrate the competency attained in Smith & Veitch's experiment, the metric selected for comparison from the SBML experiment was performance in the participant's successful testing scenario. This score was then contrasted by the participant's performance score on the first attempt in the retention experiment. This comparison is shown in Figure 14.

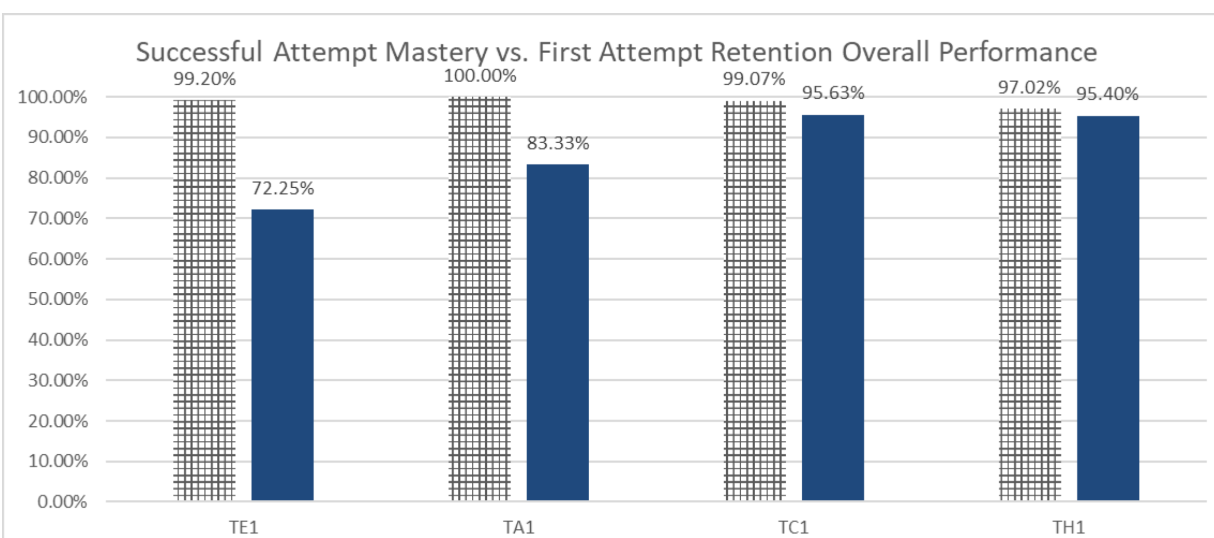

Figure 14: Successful Attempt SBML versus First Attempt Retention - Overall Performance

The comparison in Figure 14 shows a clear difference in performance for testing scenarios TE1 (with a difference of 26.95%) and TA1 (with a difference of 16.67%). However, the performance difference lessens drastically in scenarios TC1 and TH1. To determine if there was a statistically significant difference in performance, the non-parametric tests were conducted. This allowed the successful attempt (passing attempt) performance from the SBML experiment to be compared to the first attempt performance during the retention study. To conduct the Wilcoxon Ranked Sign test, and the Sign tests (as discussed in Section 4.2.2), the scoring difference between participants in each testing scenario was tabulated. Any data points excluded from the analysis are discussed in section 4.3: Outliers and Excluded/Adjusted Data Points.

The non-parametric tests conducted in Table 31 show that the difference between aggregated successful attempt performance in Smith & Veitch's (2017, 2018) SBML experiment, and first attempt performance in the retention experiment, was statistically significant for testing scenarios TE1 and TA1. This indicates that the null hypothesis can be rejected within the context of overall first attempt performance for these two testing scenarios. These results are aligned with the original hypothesis that skill fade would be evident across the retention interval. It is interesting that this skill fade is only observed in earlier testing scenarios and not in testing scenarios TC1 and TH1, where scenario difficulty is increased.

Table 31: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Overall Performance

Non-Parametric Test Summary							
TE1		**TA1**		**TC1**		**TH1**	
Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No
Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0
Wilcoxon P-Value	<0.0001	Wilcoxon P-Value	<0.0001	Wilcoxon P-Value	0.0161	Wilcoxon P-Value	0.9799
Sign Test Result	Median ≠ 0	Sign Test Result	Median ≠ 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0
Sign Test P-Value	<0.0001	Sign Test P-Value	<0.0001	Sign Test P-Value	0.1406	Sign Test P-Value	0.8036
Significant Result?	Yes	Significant Result?	Yes	Significant Result?	No	Significant Result?	No

Table 31 shows that the result of the non-parametric tests conflicted for testing scenario TC1. To determine which test would take precedence, the distribution of the data was observed on a histogram. One of the assumptions of the Wilcoxon Signed Rank test is that the distribution will be roughly symmetric about the median. However, it is clear from the histogram shown in Figure 15 that the distribution violates this assumption. As a result, the Sign test takes precedence.

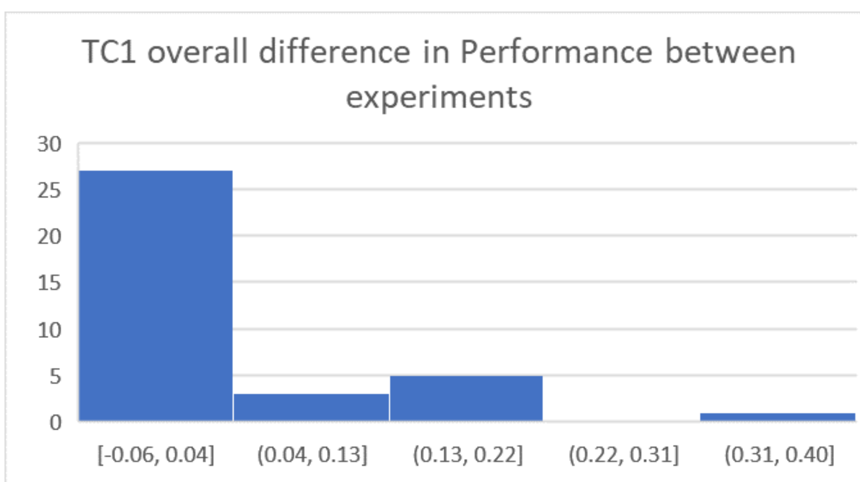

Figure 15: Histogram of difference in overall performance for testing scenario TC1

4.2.2.3: LO1 & LO2: Spatial Awareness & Alarm Recognition

The non-parametric test summary for LO1 and LO2 can be seen in Table 32 below. LO1 is first introduced in testing scenario TE1, and LO2 is first introduced in testing scenario TA1. The tests determined that there was a statistically significant difference in testing scenario

TE1. This result allows for the null hypothesis to be rejected with 95% confidence. In other words, the participants' ability reach the correct muster station deteriorated significantly over the retention interval for testing scenario TE1. In the following testing scenarios, the non-parametric test results indicate that the participants' spatial awareness and ability to recognize alarms was not significantly different compared to the competence level achieved in the SBML study.

Table 32: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Spatial Awareness and Alarm Recognition (LO1 & LO2)

Non-Parametric Test Summary - LO1 & LO2							
TE1		**TA1**		**TC1**		**TH1**	
Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No
Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0	Wilcoxon Result	Median = 0	Wilcoxon Result	Median = 0
Wilcoxon P-Value	0.0156	Wilcoxon P-Value	0.25	Wilcoxon P-Value	1	Wilcoxon P-Value	1
Sign Test Result	Median ≠ 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0
Sign Test P-Value	0.0156	Sign Test P-Value	0.25	Sign Test P-Value	1	Sign Test P-Value	1
Significant Result?	Yes	Significant Result?	No	Significant Result?	No	Significant Result?	No

This is an interesting result. At the beginning of the retention experiment, the average performance is notably lower than the post training levels after completing the SBML experiment (see Figure 16). After the initial testing scenario, performance increases significantly in TA1 and reaches close to post training competency levels during testing scenarios TC1 and TH1.

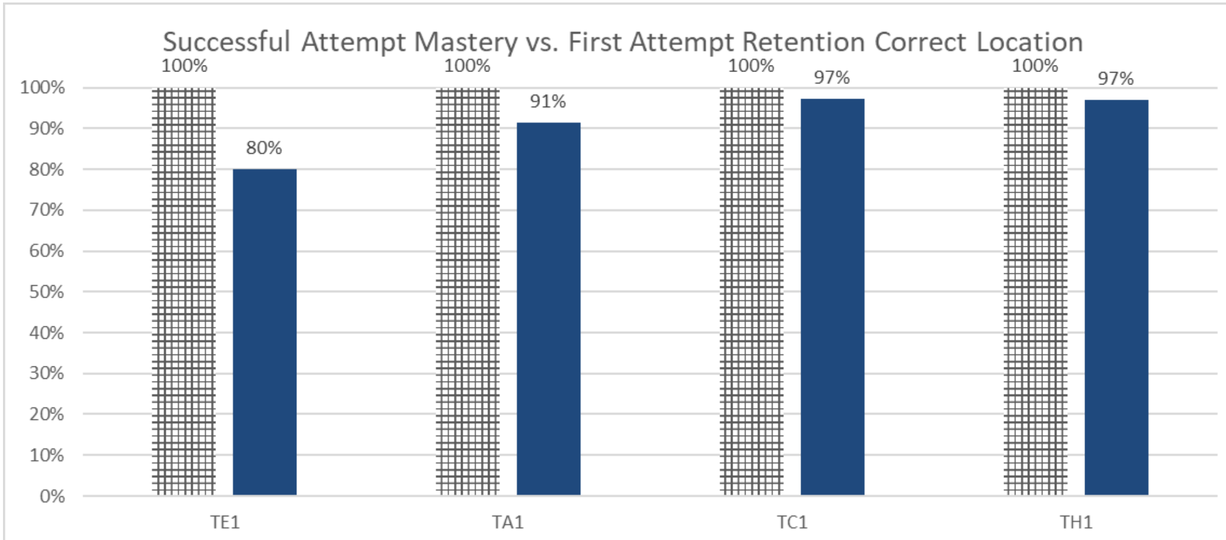

Figure 16: Successful Attempt SBML versus First Attempt Retention - LO1 & LO2 Spatial Awareness and Alarm Recognition

4.2.2.4: LO3 & LO4: Routes & Assessing Emergency Situations

The non-parametric test summary for LO3 and LO4 can be seen in Table 33. LO3 is first introduced in testing scenario TE1, and LO4 is first introduced in testing scenario TC1. The tests determined that there was a statistically significant difference between the successful attempt performance in the SBML experiment, and the first attempt in the retention experiment for scenario TE1. This result allows for the null hypothesis to be rejected with 95% confidence, meaning that the participants' ability to follow routes was significantly different in testing scenario TE1. Conversely, in remaining testing scenarios the test results accept the null hypothesis and show that participant performance did not change between the two experiments.

Table 33: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Route Selection and Hazard Response (LO3 & LO4)

Non-Parametric Test Summary - LO3 & LO4							
TE1		**TA1**		**TC1**		**TH1**	
Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No
Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0	Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0
Wilcoxon P-Value	<0.0001	Wilcoxon P-Value	0.5	Wilcoxon P-Value	0.0332	Wilcoxon P-Value	0.6722
Sign Test Result	Median ≠ 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0
Sign Test P-Value	0.0001	Sign Test P-Value	0.5	Sign Test P-Value	0.2266	Sign Test P-Value	0.7744
Significant Result?	Yes	Significant Result?	No	Significant Result?	No	Significant Result?	No

Table 33 shows that the results of the non-parametric tests conflicted for testing scenario TC1. To determine which test would take precedence, the distribution of the data was observed on a histogram, which is shown in Figure 17. It is clear from the histogram that the distribution is not symmetric about the median, thus the Sign test takes precedence.

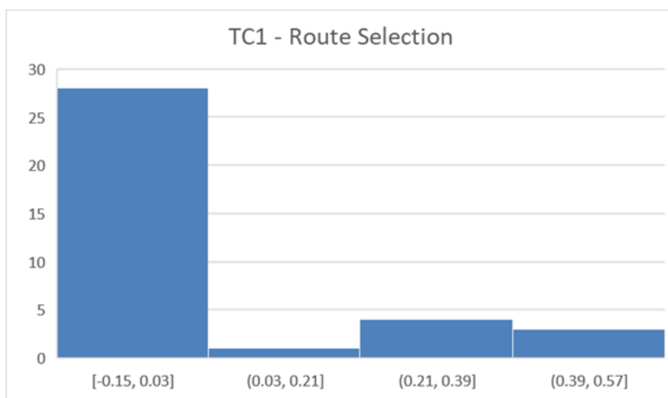

Figure 17: Histogram of difference in LO3 & LO4 performance for testing scenario TC1

Figure 18 shows that the mean performance between experiments is shown to fluctuate as the experiment proceeds. In scenario TE1, the performance in the retention experiment is quite low, and then returns almost to post training levels during testing scenario TA1. The performance then decreases (to 91%) for scenario TC1 and then improves again for scenario TH1 (to 93%). This drop in performance is likely due to the introduction of LO4 in testing scenario TC1. LO4 requires that participants dynamically respond to hazards in the simulation environment resulting in increased scenario difficulty.

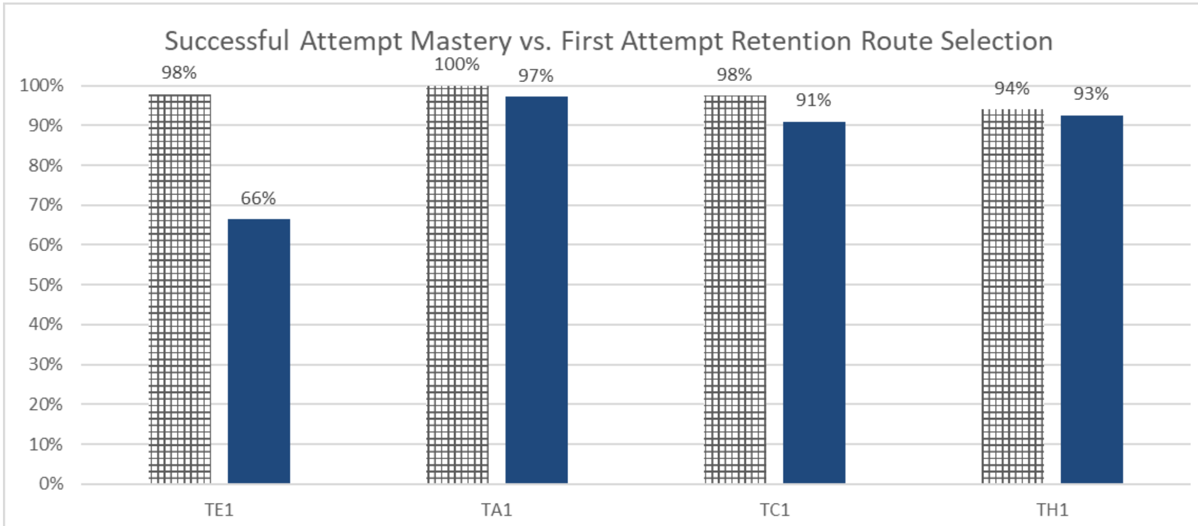

Figure 18: Successful Attempt SBML versus First Attempt Retention - LO3 & LO4 Route Selection and Hazard Response

4.2.2.5: LO5: Mustering Procedure

The non-parametric test summary for LO5 can be seen in Table 34. Only testing scenarios TA1, TC1, and TH1 were included in the analysis because LO5 was not present in scenario TE1, and this learning objective first appears in testing scenario TA1. The non-parametric tests determined that there was a statistically significant difference in scenario TA1 between the successful attempt performance in the SBML experiment, and the first attempt in the retention experiment. This result allows for the null hypothesis to be rejected with 95% confidence, indicating that the participants' ability to successfully complete the muster procedure changed over time.

Table 34: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Mustering Procedure (LO5)

Non-Parametric Test Summary -LO5							
TE1		TA1		TC1		TH1	
Dataset Normal?	N/A	Dataset Normal?	No	Dataset Normal?	No	Dataset Normal?	No
Wilcoxon Result	N/A	Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0	Wilcoxon Result	Median = 0
Wilcoxon P-Value	N/A	Wilcoxon P-Value	0.0001	Wilcoxon P-Value	1	Wilcoxon P-Value	1
Sign Test Result	N/A	Sign Test Result	Median ≠ 0	Sign Test Result	Median = 0	Sign Test Result	Median = 0
Sign Test P-Value	N/A	Sign Test P-Value	0.0001	Sign Test P-Value	1	Sign Test P-Value	1
Significant Result?	N/A	Significant Result?	Yes	Significant Result?	No	Significant Result?	No

The null hypothesis must be accepted for testing scenarios TC1 and TH1 as the non-parametric tests did not find a significant difference in performance. This is supported by the comparison shown in Figure 19, which shows that participants initially have difficulty completing the mustering procedure correctly during the initial re-exposure, but return to post training competence in the later testing scenarios.

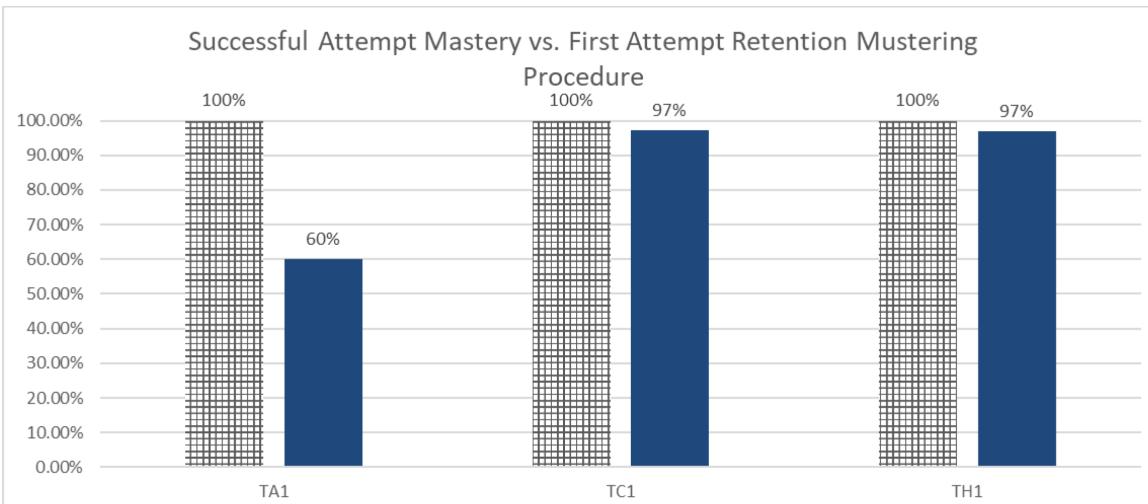

Figure 19: Successful Attempt SBML versus First Attempt Retention - LO5 Mustering Procedure

4.2.2.6: LO6: Safe Practices

Figure 20 and Figure 21 below show the average performance for safe practices (not running and closing fire doors) in both experiments. In scenarios TC1 and TH1, participants demonstrated 100% competence in both practices for each experiment. Participants also demonstrated 100% competence in scenario TA1 with regards to running. For this reason, it was impossible to conduct a statistical test for many of the testing scenarios (if 100% competency is demonstrated in both experiments it is impossible to test for a difference in performance). However, the non-parametric tests were conducted for scenarios where mathematically possible.

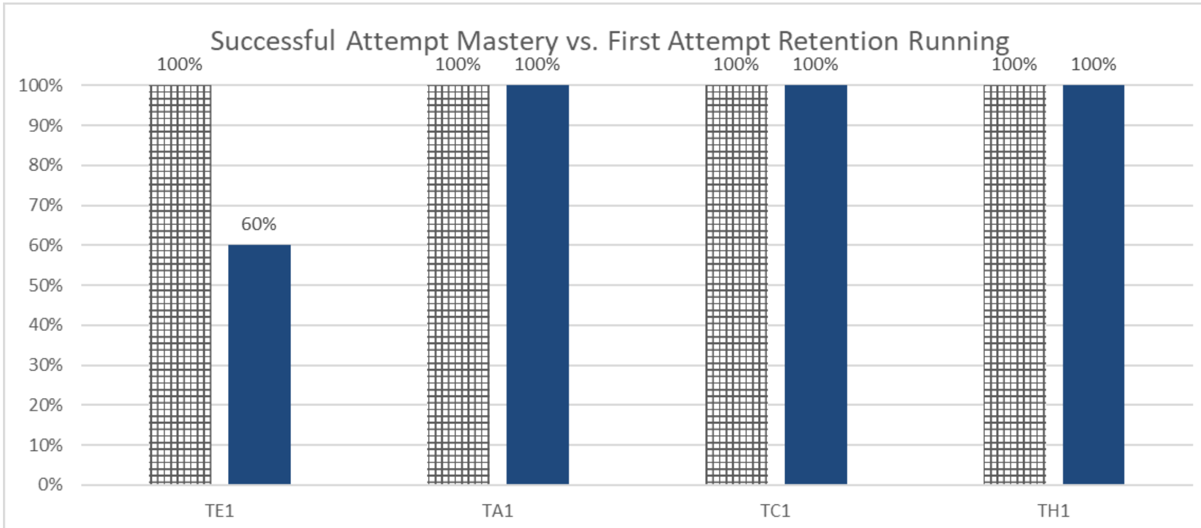

Figure 20: Successful Attempt SBML versus First Attempt Retention - LO6 Running

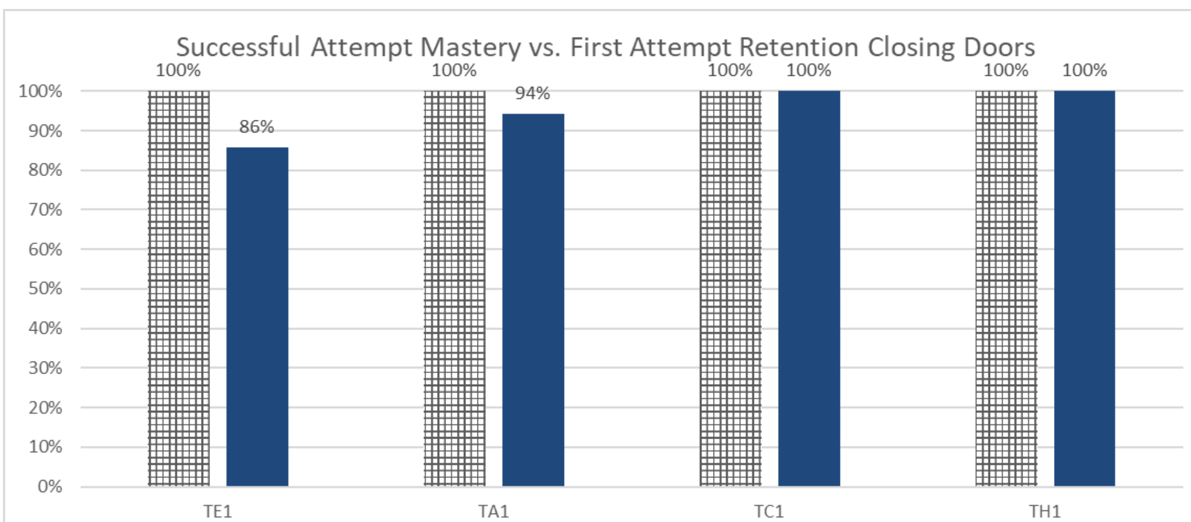

Figure 21: Successful Attempt SBML versus First Attempt Retention - LO6 Fire Tight Doors

The non-parametric summary for LO6 can be seen in Table 35. The left side of the table shows a summary of participants who chose to run during the simulation. The right side of the table shows the participants who forgot to close fire doors. The non-parametric tests regarding running for testing scenario TE1 determined that there was a statistically significant difference in the performance between both experiments, allowing for the null hypothesis to be rejected with 95% confidence.

The tests also concluded that there were no statistically significant differences in performance with regards to closing fire tight doors. A closer examination of the p-values for testing scenario TE1 indicates that neither test conducted allows for the null hypothesis to be rejected, however the p-values are very close to the acceptance criteria of 0.05.

Table 35: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Running [Left] and Fire Tight Doors [Right] (LO6)

Non-Parametric Test Summary - LO6							
TE1 - Running			**TE1 - Doors**		**TA1 - Doors**		
Dataset Normal?	No		Dataset Normal?	No	Dataset Normal?	No	
Wilcoxon Result	Median ≠ 0		Wilcoxon Result	Median = 0	Wilcoxon Result	Median = 0	
Wilcoxon P-Value	0.0001		Wilcoxon P-Value	0.0625	Wilcoxon P-Value	0.5	
Sign Test Result	Median ≠ 0		Sign Test Result	Median = 0	Sign Test Result	Median = 0	
Sign Test P-Value	0.0001		Sign Test P-Value	0.0625	Sign Test P-Value	0.5	
Significant Result?	Yes		Significant Result?	No	Significant Result?	No	

4.2.2.7: LO7: First Actions and Effective use of PPE

The non-parametric test summary for LO7 can be seen in Table 36. LO7 first appears in testing scenario TA1 and only testing scenarios TA1 and TH1 were included in the analysis. TE1 was excluded from the analysis because participants were not required to demonstrate LO7 as part of the scenario. TC1 was excluded from the analysis because the non-parametric tests could not be conducted (performance in both experiments was at 100% competence, as shown in Figure 22 below).

Table 36: Non-Parametric Test Results - Successful Attempt SBML versus First Attempt Retention for Effective Use of PPE (LO7)

Non-Parametric Test Summary - LO7			
TA1		**TH1**	
Dataset Normal?	No	Dataset Normal?	No
Wilcoxon Result	Median ≠ 0	Wilcoxon Result	Median = 0
Wilcoxon P-Value	>0.0001	Wilcoxon P-Value	0.125
Sign Test Result	Median ≠ 0	Sign Test Result	Median = 0
Sign Test P-Value	>0.0001	Sign Test P-Value	0.125
Significant Result?	Yes	Significant Result?	No

The non-parametric tests determined that there was a statistically significant difference between the successful attempt performance in the SBML experiment, and the first attempt in the retention experiment in testing scenario TA1. This result allows for the null hypothesis to be rejected with 95% confidence. In other words, the participants' ability to locate, collect, and use safety equipment deteriorated over the retention interval. The non-parametric test results also showed that the null hypothesis must be accepted for test scenario TH1, indicating that there was no statistically significant difference in performance between the two experiments.

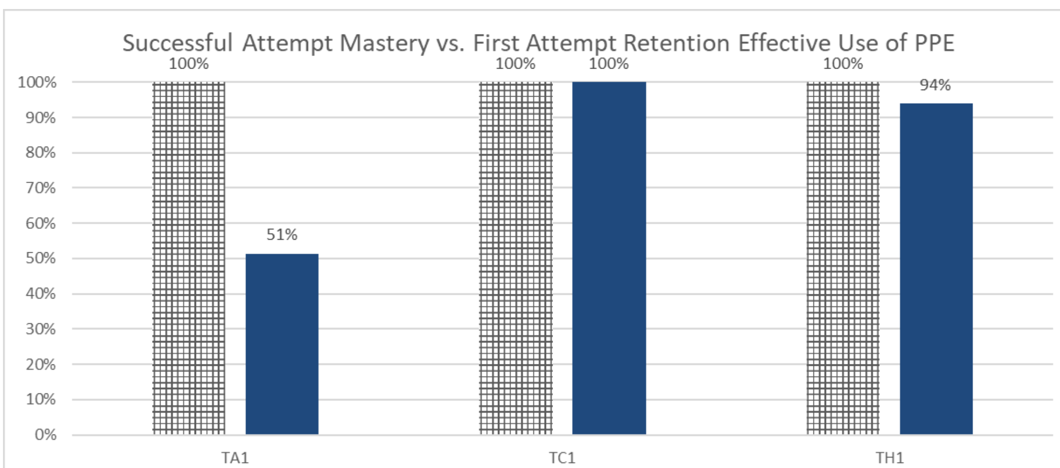

Figure 22: Successful Attempt SBML versus First Attempt Retention - LO7 Effective use of PPE

4.3: Outliers and Excluded/Adjusted Data Points

4.3.1: Dataset Outliers

The data collected for both participants A09 and A62 were excluded from the dataset analyzed in this thesis as they represented significant temporal outliers. Participant A62 completed the retention study after a period of only four months, while participant A09 completed the study after a period of ten months. These irregular intervals occurred due to participant availability. The participants were excluded from the overall dataset to preserve the retention interval under evaluation.

4.3.2: Data Points Excluded from Statistical Tests

Other null data points may be noted throughout the evaluated datasets and were excluded from the statistical analysis. Although both experiments were conducted using the same scoring rubric, the nullified points were identified as having inconsistent scoring between experiments. A comprehensive representation of the data may be found in Doody & Veitch's (2017) report. The null data points of interest are as follows:

- TE1 – Participant A24
- TA1 – Participant A18
- TH1 – Participant A03, A15, and A47

4.3.3: Data Points Altered to Reflect Accurate Scoring

Two participants in the Retention experiment required score alteration after the experiment concluded. During the data analysis, a scoring inconsistency was noted in the retention experiment dataset. Namely, two participants in testing scenario TC1 were forced to repeat the testing scenario despite having completed the scenario successfully. This mistake was identified as experimenter error. It had minimal impact on the dataset.

To address this inconsistency, two options were available. Option 1 was to nullify those data points and all points following the error; option 2 was to reduce the trials to competence score to the correct value and continue the analysis as if they had succeeded on the first attempt. Option 2 was selected as the error did not result in the participant receiving additional training that would help them to succeed in the final testing scenario. Instead, it reviewed skills in which the participant had already demonstrated competence. The data points of interest are as follows:

- TC1 – Participant A24

- TC1 – Participant A35

4.4: Summary of Results

In this thesis, several tests were conducted to evaluate the effectiveness of the AVERT training platform in teaching skills over a period of six to nine months. The results of the non-parametric tests demonstrated that there were several metrics that had statistically significant differences in performance over the retention interval. The significant differences in performance are as follows:

- Overall Performance: TE1 & TA1
- LO1 & LO2: TE1
- LO3 & LO4: TE1
- LO5: TA1
- LO6: TE1 (with regards to running)
- LO7: TA1

Most of the significant differences in performance across the two scenarios occur in testing scenarios TE1 and TA1. This observation is especially interesting when the learning objectives that are present in each scenario are considered. Testing scenario TE1 is comprised of LO1, LO3, and LO6, and TA1 is comprised of the same learning objectives, but incorporates LO1 with LO2, and includes LO5 and LO7. The final learning objective, LO4 is then introduced in TC1. This leads to the conclusion that skill fade is evident in the scenario where participants are re-exposed to the learning objective for the first time after the retention interval. Another interesting observation is that significant differences generally cease to exist after the initial re-exposure to each learning objective, demonstrating that participants who are not competent after the retention interval can be rapidly retrained to competency. This result is further demonstrated when LO4 (i.e. emergency response) is first introduced in testing scenario TC1. Route selection performance generally improved over the course of the retention experiment and increased to post training levels by testing scenario TA1. However, when participants were required to respond to hazards in the environment, overall performance dropped again. This conclusion is confirmed through the improved pass rate demonstrated by participants during their second attempt at each testing scenario.

The results of the Pearson chi square test used to evaluate the experimental trials to competence yielded interesting results. For testing scenarios TE1 and TA1 (the scenarios that cover basic knowledge and safety procedures) the observed chi-square value was found to be greater than the expected value from the chi-square distribution. This result indicates that there was a difference between the repeated measures in testing scenarios TE1 and TA1. The converse is valid for scenarios TC1 and TH1, as they were evaluated to have a lower chi-square values than expected by the distribution. This indicates that there was no difference between the repeated measures for testing scenarios TC1 and TH1. These results support the findings from the non-parametric tests and demonstrate that the retention interval had an impact on early performance in the retention study.

4.5: Potential Sources of Error

There are several potential sources of error that may have affected the results of this experiment. Steps were taken throughout the experiment execution to mitigate their impact on the dataset. The potential sources of error with their remediation are as follows:

1. Data collected in this experiment was infrequently collected by different researchers

- At times this variation in data collection was unavoidable due to scheduling conflicts between the researcher and research participants and was identified prior to the start of the experiment. To preserve data validity, co-investigators practiced running each experiment using the experimental script shown in Appendix A. This activity provided an opportunity for the researcher to coach the co-investigator in correct experiment execution, ensuring that data collection and participant management was consistent in their absence.

2. Data points which were excluded from the dataset
    - This topic is discussed in detail in section 4.3.
3. Software glitch: the invisible box that stopped participants from donning the immersion suit at the starboard lifeboat station in testing scenario TH1
    - This topic is discussed in section 4.1.2.

4.6: Experimental Limitations

This thesis has examined the success rate of participants who were able to effectively recall training provided through a VE after a period of 6-9 months. Unfortunately, the dataset collected had limited information on participants who had difficulty recalling details after initial re-exposure to the training program. This is because a large fraction of the participants were quickly returned to competence after initial re-exposure to the training system. Without sufficient data statistics on the sub-group of participants who had difficulty in retention statistics could not be conducted. As a result, it is difficult to draw conclusions about the factors that influence this group. The only way this limitation can be addressed is through the collection of additional data.

Chapter 5: Discussion

5.1: Discussion of Results & Research Implications

5.1.1: Implication of Results

As stated in Section 4.4, the results of this thesis demonstrate that the hypotheses posited by the researcher were supported by the evidence. Evaluation of participant performance across both experiments demonstrated that there was clear skill fade over the retention interval and that the number of attempts required to be successful in the retention study was dependent on the number of attempts taken in the SBML experiment conducted by Smith & Veitch (2017, 2018).

An interesting observation about the experimental results was that the difference in number of attempts required to demonstrate competence, and average performance, generally were statistically significant only in the first two testing scenarios (TE1 and TA1), which is where six of the seven learning objectives were first tested. After initial re-exposure to the training content, participants were able to rapidly return to the competency level.

The observation that participants could be quickly retrained to competence indicates that the adaptive training matrices (which were developed for this experiment) were functional and effective in addressing competence gaps developed by the participants over time. This experiment demonstrated that well designed adaptive training matrices can provide flexible and effective training to users in virtual environments, which is a crucial first step towards training automation.

There is also some evidence that virtual environment training may not be the ideal platform for some people. As discussed in Section 4.1.5, a small number of participants failed to complete learning objectives on their second attempt despite having been provided with re-training content on the learning objective. The same participants who demonstrated difficulty in learning objectives despite re-training also demonstrated a poor first attempt success rate across all learning objectives.

5.1.2: Key Areas for Future Research

5.1.2.1: Is the concept of a training interval antiquated?

The results of this research have led to new questions. The first question is: has the fixed training interval become an antiquated concept, particularly in the context of automated virtual environment training? The results of this thesis determined that there was clear skill fade between the initial training to competency and the retention tests conducted six to nine months later. However, participants were easily returned to post training levels through exposure to the testing and re-training scenarios. The significant drop in participant competency indicates that there is a possibility that fixed intervals may not be the best basis for setting re-training frequency. A virtual environment training platform can be delivered "on demand", which allows for future research to explore alternatives, such as shorter sessions with higher frequency. Ideally, a participant would remain above the minimal acceptable post training competency at all times, and training would be managed to ensure that their skills did not drop below the competency standard. An example of how competency could be managed in graphical form is shown in Figure 23 below.

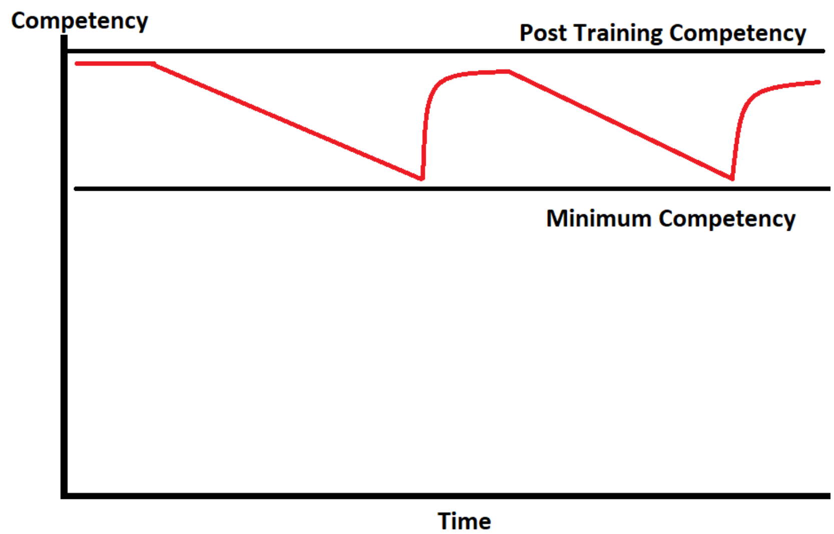

Figure 23: Ideal Competency Maintenance (after Sui et al. 2016)

Rather than sending participants to a training session at a fixed interval where all skills are reviewed, participants could be evaluated at their current competency level and then provided with targeted re-training. This approach would reduce the time spent training and would provide employers and employees with detailed feedback on the areas where personnel struggle. This information could then be used to improve the effectiveness of the training through redesigned training modules to meet the needs of the end user. Virtual environments offer a unique opportunity in this regard.

Another benefit of virtual environments is that the record keeping is automatic and consistent. Aggregated data has the capacity to present clear and unbiased information about the way that work is completed in an organization. Through targeting key areas where personnel struggle, organizations could alter operating procedures to improve safety and efficiency.

5.1.2.2: Can the training interval be dynamic/individualized?

The research question above leads to another: can training intervals be based on the needs of the individual? The results of this thesis demonstrated that training could be automated to adjust to an individual's knowledge gaps. However, the experiment did not do a detailed assessment of when a participants' competency begins to fade, or how frequently assessments should occur. The virtual environment training demonstrated that participants could be returned to post training competency levels quickly after a period of six to nine months, and that first attempt competency levels decreased across the interval.

To address this question, further research should be conducted on the topic of skill fade to determine the point at which procedural and spatial skills begin to deteriorate in a virtual environment. The results of this experiment could inform a baseline expected skill deterioration based on individual learning objectives, which could then become an input to the assessments suggested in section 5.1.2.1. Further, as additional data is collected about each participant, individualized training regimes could be developed to address individual differences in skill fade, which would assist in maintaining competency as shown in Figure 23.

Another way that this research question could be investigated in future experiments is by assuming that the skill fade has already occurred prior to the training session, as opposed to trying to measure exactly when skill fade begins to occur. In this case, the research would aim to address how significantly the skill has faded and then bring the participant back to competence. Through this methodology, participants would have their skill fade addressed immediately, and over time, the researcher could attempt to diagnose suitable retraining intervals based on individual performance metrics.

5.2: Concluding Remarks

This thesis investigated the retention of skills of naïve participants who completed a safety induction training in the AVERT virtual environment. The participants' skills were evaluated six to nine months after the original training. The data showed that there was clear skill fade over the time interval examined, and that the number of attempts required to be successful in the retention experiment was different than the number of attempts taken in the original training (Smith & Veitch 2017, 2018). Skill fade was demonstrated most prominently in the first two testing scenarios where participants were first re-exposed to the learning objectives. Participants also demonstrated the ability to be rapidly re-trained to competency. The rapid return to post training competency shows that the adaptive training matrices used to address skill fade in the experiment were effective.

Future research should focus on how simulation-based training can be designed to meet the needs of the individual. These research initiatives should concentrate on determining how individual skills can be assessed and maintained over time through the automation of training based on competency. Future research should also investigate methods to determine individual skill fade rates, so training regimes can be developed based on the competency of the individual.

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Appendix A: Experimental Script and Consent Addendum

General

This script outlines how the experiment will be conducted. A copy of the experimental script will be provided to all members of research team. If you are not familiar with the experiment procedure, please use this document as a guide.

Welcome

- Thanks for agreeing to participate in the study. We appreciate your support of this research and the time you are taking to come in.

Facility Orientation

- Show participants around the facility (EN1035). Give a brief orientation of the building (show them the washroom, and emergency exit). Include where the Lead Researcher will be sitting and the viewpoint.

Volunteer Eligibility

- All volunteers must answer the following questions to be eligible to participate (changed since last time?):

Question	Eligible Participant Answer
Prior Experience:	
1. Have you completed the Mastery of Learning Training?	**Yes.** Participants must have already completed AVERT Mastery of Learning Experiment.
2. Have you received experience working offshore since the first AVERT study?	**No.** Participants must not have any prior training or experience working offshore.
3. Do you expect to receive training to work offshore in the next 3 months?	**No.** Participants must not be expecting to receive training elsewhere during the course of the experiment.
Background Information:	
1. Are you between the ages of 18 and 65?	**Yes**
2. Do you have normal vision or corrected to normal vision (e.g. wear glasses or contacts)?	**Yes.** You must have normal or corrected to normal vision to be able to participate in this study.
3. Do you have a history of headaches or migraines?	**No.** Participants who have a history of headaches or migraines are not eligible to participate in this study.
4. Do you have a history of seizures or are you prone to seizures?	**No.** Participants who have a history of seizures or are prone to seizures are not eligible to participate in this study.
5. Are you susceptible to motion or simulator sickness?	**No.** The VE may cause symptoms of simulator sickness. Participants who have a high susceptibility to motion or simulator sickness will not be able to participate in the study.

6. Do you have any conditions that could be aggravated by anxiety?	**No.** Participants who have a medical condition that is aggravated by anxiety are not eligible to participate in this study.

Participant Responsibilities

- As a participant in this study, the research team expects you to follow the protocols put in place for your safety and that are necessary to successfully conduct the experiment.

- As a reminder these are the responsibilities expected of you as a participant:

  1.) Refrain from the use of alcohol 24 hours before any testing.

  2.) Refrain from exercise, caffeine, smoking and fasting 2 hours before to testing.

  3.) Arrive at the sessions in your usual state of health and fitness. If you are experiencing a temporary illness (e.g. experiencing hangover, flu, respiratory illness, head cold, ear infection, fatigue (sleep loss) and upset stomach) we will attempt to reschedule you within one week (if necessary).

  4.) Wear comfortable clothes.

  5.) Follow all safety precautions and behave responsibility.

  6.) Notify a member of the research team if you are uncomfortable or are experiencing symptoms or discomfort that may prevent you from continuing.

The research team reserves the right to exclude you from the study for the following reasons:

1.) if you are not following the expectations listed above,

2.) if you are at an increased risk (as outlined in the eligibility section),

3.) if you are experiencing symptoms that impact your safety or performance.

Participant Number Assignment

- You have been assigned a participant number (an alphanumeric code) at the beginning of the study (e.g. A01). The participant number is the same that was used in the initial mastery and retention study. This number will be used to label all data associated with your participation. The coding key will be stored by Kyle Doody, Allison Moyle and Jennifer Smith in a locked office in a separate place from the performance data collected.

Session Briefing

- You will be participating in two studies today
- Retention Study with Kyle Doody which will examine how well you remembered the material from the initial Mastery of Learning study
- Human Reliability Study with Allison Moyle which will example how well you can apply the knowledge learned to a realistic scenario in AVERT.
- The session length will be approximately 3 to 5 hours.

- *Kyle* will now go through the retention study consent form and study procedure. After the retention study, we will take a 15 min break. *Allison* will then review the consent form and procedure of the HRA study with you prior to starting.
- *Any Questions?*

Retention Study Details

Consent Form

- ***Sent Consent form 24 hours prior to the scheduled time for participant review.***

- Ask Participant if they reviewed the consent form prior to arriving. If Yes, get signature. If no, provide walk through and then signature. Follow script below for walk-through of consent form.

- Your signed consent form will be required before you begin your participation.

Study Briefing

- The goal of this research is to improve the safety of personnel working at sea. The research team is focused on continuing the research and development of a software-based simulation environment to prepare people for evacuating virtual offshore platforms in emergency situations. We will be conducting this experiment in AVERT just like in the last experiment.

- This study was designed to investigate learning retention with the mastery of learning approach after a period of six to nine months. Participants in this study must have completed the initial training phase using the mastery of learning approach and have not been given a medium to review the training content for a period of six months. The primary focus of this research is to evaluate the level of recall that participants exhibit from the content taught to them during the initial training phase.

- For the study you will be using the desktop version of AVERT as used in the previous study

- SEE APPENDIX A FOR GRAPHIC (how experiment will proceed) [in this thesis the graphic is Figure 2].
- This session will consist of a series of Habituation, Testing and potentially Re-training scenarios. Habituation will allow you to re-familiarize yourself with the interface and virtual environment. You will then complete the Testing Scenarios from the original study, and based on performance will move on to the next testing scenario or training scenarios. The training scenarios will be selected based on feedback from the testing scenarios.

- Before each testing scenario, we will have a 5 minute "baseline" period in order to collect physiological data. You need to relax as much as possible and to avoid talking and moving.

- After you complete the testing scenarios, please complete the SSQ.

Withdrawal

- If you decide to withdraw from the study, the information collected up to that time will be removed from the study. This information will be destroyed and will not be included in the data analysis of the study
- If you choose to withdraw from the study after data collection has ended, your data can be removed from the study up to two weeks after the completion of your participation
- Withdrawal from the study will not affect your standing with Memorial University, The School of Engineering and Applied Science, or the Virtual Environments for Knowledge Mobilization Project

Benefits & Risks

- No Direct benefits to you, but you may be contributing to the improvement of safety training in the marine, offshore industries.
- Risks include Simulator Induced Sickness, Seizures, Eye Strain. SIS includes headache, nausea, vertigo, dizziness and burping. If you experience any of these symptoms, please let us know immediately. You will be completing SSQ's throughout the trial.

Confidentiality

- We will protect your identity and personal information from unauthorized use. We will make every effort to protect your privacy. However please note that we may be required by law to allow access to research records.
- By signing you give us permission to collect information from you, share the data with people conducting the study and responsible for protecting your safety

Recording, Storing Reporting of Data

- We are collecting performance metrics, physiological data, and subjective assessments
- Performance metrics are computer based activities from your response in AVERT
- Physiological data includes stress experienced from test scenarios
- Subjective assessments in answering questionnaires on the scenarios
- Information kept for 5 years, then will be destroyed
- Findings will be published in peer reviewed journals/conferences
- Formal Reports available upon request

- Participants have up to **two weeks** to request their data not be included in the study after participation. Should this request be made the participants data will be destroyed immediately

Sign Form

- Ask Participant if they have any questions
- Ask participant to sign Consent form.

Questionnaires

- You will complete 3 questionnaires during the study today

- Simulator Sickness Questionnaire
    - The SSQ will help monitor you during the test scenarios
    - We will stop the study if they ever reach a four on the scale of any symptom
    - Ask Participant to Fill out SSQ

- Utility of Training Questionnaire
    - Assess various attributes of training tutorial and virtual environment scenarios on learning experience. These will be reported on a 7-point scale.
    - Completed at end of study.

- Post Test Scenario Questionnaire

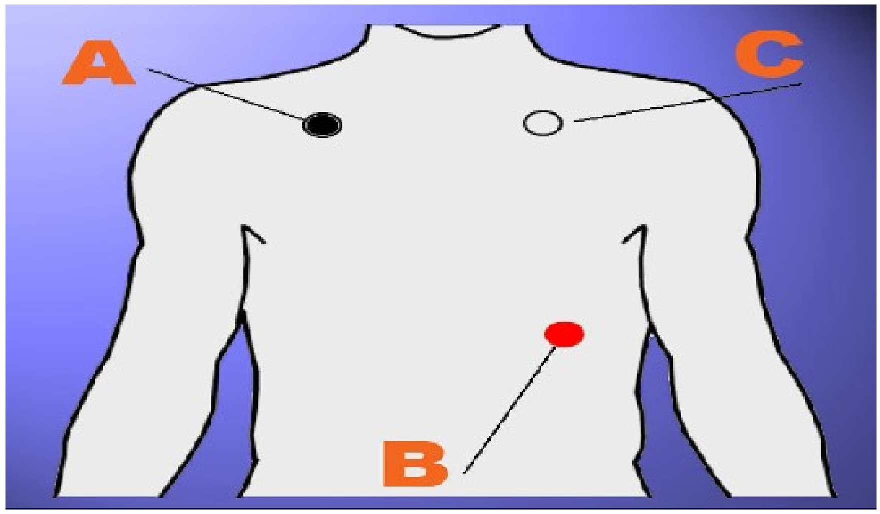
Physiological Equipment Hook Up

- An initial 5-minute baseline will be take prior to the start of the test scenarios.
- We will also take measurements as you complete each test scenario.

- During the testing scenarios we will assess the following physiological measures:

    - ECG - Measuring heart rate by placing electrodes on the chest and abdomen
    - Respiration - Measuring breathing rate by placing a strap over the ribcage
    - Galvanic skin response -Measuring skin perspiration by placing two electrodes on the middle and ring finger of your right hand
    - Skin temperature - Measuring peripheral skin temperature by placing a thermocouple between the thumb and the index finger of your right hand.

ECG Lead II chest placement



You'll be given three electrodes to place on your chest as shown in this diagram.

Placing electrodes:

1. Place the first electrode 3 fingers down from your collar bone on **your** right-hand side.
2. Place the second electrode at the end of your ribcage (under the last rib of the rib cage) on **your** left side.
3. Place the third electrode on your collar bone on the left-hand side (this is for grounding purposes).

Connecting leads:

A. The **BLACK** lead should be connected to the electrode on your top right-hand side.
B. The **RED** lead should be connected to the electrode on your bottom left-hand side.
C. The ground (WHITE lead) should be connected to the electrode on your left-hand side collar bone.

Throughout this study you may feel as though you are strapped to the chair. Please know that at any point you're free to take a break!

Objective Briefing

- During the exercise you will do a series of training and testing muster drills and evacuation situations. During the test scenarios your performance will be recorded.

- In each scenario you will demonstrate that you're able to muster correctly using the knowledge and skills learned. You will be required to select the most efficient route, muster correctly, and pay attention to your surroundings. Feedback will be given at the end of the each scenario.

- Remind of Participant Responsibilities and Right to withdraw at any time

- Please use your time wisely and focus on the scenario for the entire period.

- AVERT is used as a training simulator only and should be taken seriously. Do not treat it as a “videogame”. React to any hazards or situations as you would in a real-life setting.

- The researcher cannot answer any questions about how to do the task during the testing exercises, so please make sure to ask any questions before you start the study.

- **Good Luck!**

Final Debriefing

- Thank you for your time today. We really appreciate you volunteering your time to help us investigate the utility of the AVERT simulator.
- As a reminder, the research team intends to publish the findings of this study in peer reviewed journals and academic conferences.
- Formal reports will be made available to funding agencies and industry partners. If you would like a copy please let us know.
- Feel free to share this volunteer opportunity with your friends however please DO NOT discuss the testing session (what the trials are) with any other participants under any circumstance.

- **Have a Great day!**

Sub-Project Consent Form Addendum

Title of Sub-Project: Evaluation of performance in emergency response scenarios: A Virtual Environment Skill Retention Study

Researcher(s): Mr. Kyle Doody, Memorial University of Newfoundland Faculty of Engineering and Applied Science: Department of Ocean and Naval Architecture, Phone: (709)325-0651, Email: kdoody@mun.ca

Supervisor(s): Dr. Brian Veitch, Memorial University of Newfoundland Faculty of Engineering and Applied Science: Department of Ocean and Naval Architecture, Phone: (709)864-8970, Email: bveitch@mun.ca

My name is Kyle Doody and as part of my Master's program I am conducting research under the supervision of Dr. Brian Veitch. The details of my research are listed in the consent form for the second phase of this research project, as titled above.

In addition to participating in the research project "Evaluation of the emergency response performance of naïve subjects trained using a virtual environment (VE): A comparison of two VE interfaces," as outlined in the preceding consent form, I am asking for your consent to use your data for my sub-project. This does not alter what you will be asked to do. It is simply to inform you that your performance data as well as your responses to our subjective assessments which were collected for the purposes of the larger project will also be used by me for my own thesis.

Consent:
This is a supplement to the informed consent form for Brian Veitch's project.

Signing of the larger project's consent form and initialing this page signifies that you have read and understand this supplemental information. All information provided in the larger project's consent form regarding confidentiality, anonymity, storage of data, etc. applies equally to my project, unless otherwise stated. Once published, my thesis/dissertation will be publically available at Memorial's QEII library.

If you have any questions about your participation, or how your data will be used for this sub-project, please contact me or my supervisor using the information provided above.

__________________ ____________________

Participant Initials Date

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Appendix B: Testing Scenario Storyboards (Smith & Veitch, 2017)

TE1 - Muster Drill Trainee Briefing: In this scenario you will demonstrate that you're able to find your lifeboat station. You will start the scenario in your cabin and will need to find your lifeboat station using your primary or secondary egress route. • Trainee starts in the Cabin • Trainee is tasked by roommate with their first objective: to meet their supervisor at their lifeboat station. • Trainee navigates from the cabin to the starboard lifeboat station using either their primary or secondary egress route. • Trainee must demonstrate the use of fire and water tight doors along the route. • After they've reached the lifeboat station, their supervisor tells them to use a different route back to their cabin.	
C Deck	1. Start at Cabin 2. Enter Main Stairwell (Interior or Exterior)
	3. Using Main (interior or exterior) Stairwell, go down 2 decks to A Deck.
A Deck	4. Exit Main Stairwell 5. Arrive at Lifeboat Station 6. Told to find way back to cabin using an alternative acceptable route
	8. Using Main (interior or exterior) Stairwell, Go up 2 decks to C Deck.
C Deck	9. Exit Main Stairwell (interior or exterior) 10. End at Cabin

TA1 - Muster Drill Trainee Briefing:

In this scenario you will be practicing a muster drill. You will start the scenario in your cabin and will need to recognize the alarm and respond accordingly.

Scenario Summary:

- Trainee starts in the Cabin
- The GPA sounds followed by a PA announcement notifying of a man overboard (MOB) drill.
- The Trainee must go to their primary muster station.
- The Trainee must take the necessary PPE (grab bag, smoke hood and immersion suit)
- The Trainee navigates from the cabin to the mess hall using either their primary egress route.
- The Trainee must demonstrate the use of fire and water tight doors along the route.
- Once at the muster station, they must notify the muster checker they've mustered by moving their T-card from 'steady' to 'mustered' and await further instructions from the muster checker.
- After a short time the exercise is completed and all personnel are cleared to return to work through a PA announcement.
- After they've given the all clear the Trainee can return to their cabin.

<u>Other Scenario Notes:</u>
MOB drill – simulating a man overboard situation; POB count
Rescue boat time – deck A Port side for MOB recovery
ERT – upper deck fire team room.

C Deck	1. Start at Cabin 2. General Platform Alarm Sounds 3. PA: Muster Drill Simulating Man Overboard 7 4. Take Immersion Suit and Grab Bag
	4. The Trainee most efficient route available to get to their muster station.
C Deck	5. Enter Main Stairwell
	6. Using Main Stairwell, Go down 2 decks to A Deck**.**
A Deck	7. Exit main stairwell 8. Arrive at muster station 9. Move t-card to mustered position

	10. Once at the muster station, the Trainee must register by moving their T-Card on the musterboard and await further instructions from the muster checker. 11. After a short time the exercise is completed and all personnel are cleared to return to work through a PA announcement.
A Deck	12. PA Announces that the drill is over and personnel can return to work 13. Move t-card back to steady position 14. Leave muster station 15. Enter either stairwell
	16. The Trainee then returns to their cabin using stairwell (Interior or Exterior), go up 2 decks to C Deck
C Deck	17. Exit either stairwell 18. Arrive at cabin

TC1 - Muster Drill Trainee Briefing:	
In this scenario you will be practicing a muster drill. You will start the scenario in your cabin and will need to recognize the alarm and respond accordingly.	
Scenario Summary: The Trainee starts in their Cabin, the GPA alarm sounds followed by a PA notifying of a muster drill (fire exercise – smoke in venting on B-Deck). The Trainee must take the necessary PPE (grab bag, smoke hood and immersion suit) and go to their muster station. In this scenario, the primary route is obstructed with Fire Team activities (e.g. Block route for firefighting efforts). The Trainee must re-route to secondary route or most efficient route available to get to their muster station. Once at the muster station, the Trainee must register by moving their T-Card on the muster board and await further instructions from the muster checker. After a short time the exercise is completed and all personnel are cleared to return to work through a PA announcement. The Trainee then returns to their cabin.	
C Deck	1. Start at Cabin 2. GPA Sounds 3. PA: Fire drill blocking main stairwell at B deck 4. Take immersion suit and grab bag
	5. Emergency Response Teams gather at simulated fire situation on B Deck The primary route is obstructed with Fire Team activities.
B Deck	6. Fire team is on the scene (trainee must avoid hazard)
	7. The Trainee must re-route to secondary route or most efficient route available to get to their muster station.
C Deck	8. Enter main stairwell (exterior)
	9. Using Main Stairwell (Exterior), Go down 2 decks to A Deck.
A Deck	10. Exit main stairwell 11. Arrive at muster station 12. Move t-card

<table>
<tr><td colspan="2"></td><td>13. Once at the muster station, the Trainee must register by moving their T-Card on the musterboard and await further instructions from the muster checker.

14. After a short time the exercise is completed and all personnel are cleared to return to work through a PA announcement.</td></tr>
<tr><td>A Deck</td><td colspan="2">15. PA: announces drill is over, all can return to work
16. Move t-card back to steady position
17. Leave muster station
18. Enter either stairwell</td></tr>
<tr><td></td><td colspan="2">19. The Trainee then returns to their cabin using stairwell (Interior or Exterior), go up 2 decks to C Deck</td></tr>
<tr><td>C Deck</td><td colspan="2">20. Exit either stairwell
21. Arrive at cabin</td></tr>
</table>

TH1 – Evacuation Scenario Trainee Briefing:	
In this scenario you will demonstrate that you're able to respond to an emergency situation. You will start the scenario in your cabin, an alarm will sound and you will need to recognize the alarm and respond accordingly.	
Scenario Summary: • Trainee starts in the Cabin • The general platform alarm (GPA) sounds. The offshore installation manager explains over the PA that there is a fire in the galley. He directs all personnel to their primary muster stations immediately. • The Trainee must the necessary PPE (grab bag, smoke hood and immersion suit) and go to their primary muster station as quickly as possible. • In this scenario, the primary route is obstructed with smoke and the Fire Team activities (e.g. Block route for firefighting efforts). • During their egress, the situation escalates because smoke has engulfed the adjacent mess hall muster station resulting in the 'prepare to abandon platform alarm' (PAPA). • The offshore installation manager explains over the PA that the primary muster station (mess hall) is compromised by smoke so they must go to their alternate muster point (their lifeboat station). • The Trainee navigates from the cabin to the starboard lifeboat using either their primary or secondary egress route. If they do not follow the secondary route (instead take the primary route), they must re-route to their lifeboat station at some point during egress and avoid coming in contact with the smoke. • The Trainee must demonstrate the use of fire and water tight doors along the route. • Once at the lifeboat station, they must notify the lifeboat coxswain they've mustered by moving their T-card from 'steady' to 'mustered' slot on the musterboard. • The Trainee must don their immersion suit at the lifeboat station and wait at the lifeboat station and follow the directions of the lifeboat coxswain.	
C Deck	1. Start at Cabin 2. GPA Sounds 3. PA: Fire in the galley. All personnel to muster station 4. Take immersion suit and grab bag
	5. Emergency Response Teams gather at fire situation on A Deck (galley) The primary route is obstructed with smoke and Fire Team activities. Place 2-3 avatars dressed in firefighting gear at main stairwell A deck and other areas surrounding fire/smoke areas.
A Deck	6. Fire team one scene 7. PAPA Alarm Sounds 8. PA: Smoke has spread to the mess hall. All personnel to the lifeboat stations
	9. Situation escalates and smoke compromises mess hall. Prepare to abandon platform alarm is sounded and personnel are directed to their lifeboat stations as a precaution.
C Deck	10. Enter outside stairwell

	11. The Trainee must re-route to secondary route (using the outside stairwell) or most efficient route available (depending on how far along the primary route they've gone) to get to their lifeboat station. 12. Using Main Stairwell (Exterior), Go down 2 decks to A Deck.
A Deck	13. Exit main stairwell 14. Arrive at lifeboat station
	15. Once at the lifeboat station, the Trainee must register by moving their T-Card on the musterboard. Place one avatar to represent lifeboat coxswain. Place 3-5 avatars dressed in immersion suits at all lifeboat stations (lined up to board lifeboat). Place 2-3 avatars dressed in coveralls at the immersion suit cabinets. 16. The trainee must don immersion suit at lifeboat station. 17. Await further instructions from the lifeboat coxswain. 18. Scenario ends at lifeboat station.

Appendix C: Manual Data Collection Templates and Report File Sample

AVERT Observation Log

Date: ______________________________ Participant No: ___________________________________

Habituation

Attempt 1

SSQ completed? ___________________________ Symptoms of SSQ:_______________________

Observations:

____
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Attempt 2

SSQ completed? ___________________________ Symptoms of SSQ:_______________________

Observations:

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Attempt 3

SSQ completed? ___________________________ Symptoms of SSQ:_______________________

Observations:

____
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____
_____

Test Scenario (TE1)

Date: ____________________________ Participant No: ________________________________

Attempts to be successful: __________________

<u>Attempt 1:</u>

Start time: ____________________________ End time: ______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: __________________________

<u>Attempt 2:</u>

Start time: ____________________________ End time: ______________________________

Observations:

____
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Retraining Required? _________ Scenarios to Complete: __________________________

<u>Attempt 3:</u>

Start time: _____________________________ End time: ______________________________

Observations:

____
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____
____

Retraining Required? _________ Scenarios to Complete: __________________________

SSQ completed? ___________________________
Symptoms of SSQ: ______________________

Test Scenario (TA1)

Date: ______________________________ Participant No:
____

Attempts to be successful: ____________________

Attempt 1:

Start time: ______________________________ End time: ________________________________

Observations:

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Retraining Required? _________ Scenarios to Complete:
____

Attempt 2:

Start time: ______________________________ End time: ________________________________

Observations:

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____

Retraining Required? _________ Scenarios to Complete:
____

Attempt 3:

Start time: _______________________________ End time: ________________________________

Observations:

____
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____

Retraining Required? _________ Scenarios to Complete: __________________________

SSQ completed? __________________________
Symptoms of SSQ: _____________________

Test Scenario (TC1)

Date: _____________________________ Participant No: __________________________________

Attempts to be successful: ___________________

Attempt 1:

Start time: _____________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: ___________________________

Attempt 2:

Start time: _____________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: ___________________________

Attempt 3:

Start time: ______________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: __________________________

SSQ completed? __________________________
Symptoms of SSQ: ______________________

Test Scenario (TH1)

Date: _____________________________ Participant No: ___________________________________

Attempts to be successful: ___________________

Attempt 1:

Start time: _____________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: __________________________

Attempt 2:

Start time: _____________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: __________________________

Attempt 3:

Start time: ______________________________ End time: _______________________________

Observations:

____
____
____
____
____

Retraining Required? _________ Scenarios to Complete: __________________________

SSQ completed? __________________________
Symptoms of SSQ: _____________________

Training Block 1 (use as required)

B1S1

Did not meet compliance in test scenario: _________________ Attempt #: ________________

Tutorial Slide - Time: ________________________

Attempts to be successful: ___________________
Scenario - Times:___________________________

Observations:____
____
____
____
____

B1S2

Did not meet compliance in test scenario: _________________ Attempt #: ________________

Tutorial Slide - Time:________________________

Attempts to be successful: ___________________
Scenario - Times:___________________________

Observations:____
____
____
____
____

B1S3

Did not meet compliance in test scenario: _________________ Attempt #: _____________

Tutorial Slide - Time:________________________

Attempts to be successful: ___________________ Scenario -
Times:___________________________

Observations:____
____
____
____
____

Training Block 2 (use as required)

B2S1

Did not meet compliance in test scenario: ________________ Attempt #: _______________

Tutorial Slide - Time: _______________________

Attempts to be successful: __________________
Scenario - Times:__________________________

Observations:____
____
____
____
___

B2S2

Did not meet compliance in test scenario: ________________ Attempt #: ____________

Tutorial Slide - Time:_______________________

Attempts to be successful: __________________
Scenario - Times:__________________________

Observations:____
____
____
____
___

Training Block 3 (use as required)

B3S1

Did not meet compliance in test scenario: ________________ Attempt #: ________________

Tutorial Slide - Time: ________________________

Attempts to be successful: ___________________
Scenario - times:___________________________

Observations:____
____
____
____
____

SSQ completed? __________________________
Symptoms of SSQ:______________________

Training Block 4 (use as required)

B4S1

Did not meet compliance in test scenario: ________________ Attempt #: _______________

Tutorial Slide - Time: _______________________

Attempts to be successful: __________________
Scenario - Times:__________________________

Observations:____
____
____
____
____

B4S2

Tutorial Slide - Time:_______________________

Attempts to be successful: __________________
Scenario - Times:__________________________

Observations:

____
____
____
____
____

Post Test Scenario Questionnaire

Participant Number: _____________
Test Scenario: _____________
Attempt Number: _____________

1. How realistic was the scenario?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all Very realistic

2. How challenging was the scenario?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Easy Medium Hard

3. What did you find most challenging in completing the scenarios? What did you find was most difficult to recall when completing the scenario again for the first time?

____

____

4. What do you think are important factors for success in the scenarios? What did you find was the easiest to recall when completing the scenario again for the first time?

____

____

5. Did you have a strategy to learn the environment and respond to scenarios? Y / N

If yes, please briefly describe your strategy.

____

____

6. Did you have enough time to complete the scenarios in the way you would have wanted?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Not enough time Too much time

7. Do you have any feedback regarding how this scenario could be improved?

Kennedy Simulator Sickness Questionnaire

Kennedy, R. S., Lane, N. E., Berebaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. *International Journal Of Aviation Psychology*, 3(3), 203-220.

Participant Number: ______________________________________ Date:__________________________

Time:___________________
When: After / Before Testing

Please indicate the severity of symptoms that apply to you right now.

Symptom	0 No Symptoms	1 Minimal	2 Moderate	3 Severe
General Discomfort				
Fatigue				
Headache				
Eyestrain				
Difficulty Focusing				
Increased Salivation				
Sweating				
Nausea				
Difficulty Concentrating				
Fullness of Head				
Blurred Vision				
Dizzy (eyes open)				
Dizzy (eyes closed)				
Vertigo				
Stomach Awareness				
Burping				

Post Test Scenario Questionnaire

Participant Number: _____________
Test Scenario: _____________
Attempt Number: _____________

1. How realistic was the scenario?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all — Very realistic

2. How challenging was the scenario?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Easy — Medium — Hard

3. What did you find most challenging in completing the scenarios? What did you find was most difficult to recall when completing the scenario again for the first time?

____

____

4. What do you think are important factors for success in the scenarios? What did you find was the easiest to recall when completing the scenario again for the first time?

____

____

5. Did you have a strategy to learn the environment and respond to scenarios? Y / N

   If yes, please briefly describe your strategy.

____

____

6. Did you have enough time to complete the scenarios in the way you would have wanted?

☐ ☐ ☐ ☐ ☐ ☐ ☐

Not enough time — Too much time

7. Do you have any feedback regarding how this scenario could be improved?

Sample Report File

00:06:52.774 - Start Scenario

00:06:52.774 - AVERT 2.1

00:06:52.774 - TH1

00:06:52.774 - ----------

00:06:52.774 - Loc: X=-8884.097 Y=505.152 Z=3874.939

00:06:52.774 - Rot: -97.811401

00:06:54.757 - Alarm State Change: General Platform Alarm

00:06:54.774 - Rot: -50.536724

00:06:55.774 - Rot: -165.552704

00:06:56.358 - Start Moving

00:06:56.774 - Loc: X=-8925.308 Y=510.664 Z=3874.939

00:06:56.774 - Rot: 168.204636

00:06:56.824 - Stop Moving

00:06:57.124 - Start Moving

00:06:57.774 - Loc: X=-9009.185 Y=516.528 Z=3874.939

00:06:58.224 - Stop Moving

00:06:58.774 - Loc: X=-9067.157 Y=517.708 Z=3874.939

00:06:58.774 - Rot: 113.49884

00:06:59.774 - Rot: 126.37368

00:07:00.208 - Gained a Item_SurvivalSuit_24

00:07:00.774 - Rot: 103.403488

00:07:01.757 - Gained a Item_GrabBag_0

00:07:01.774 - Rot: 104.088951

00:07:02.774 - Rot: 104.088951

00:07:03.774 - Rot: 178.265579

00:07:04.791 - Start Moving

00:07:05.124 - Stop Moving

00:07:05.474 - Start Moving

00:07:05.774 - Loc: X=-9136.093 Y=519.772 Z=3874.939

00:07:05.858 - Stop Moving

00:07:06.324 - Open Door_CDeck_Cabin

00:07:06.641 - Start Moving

00:07:06.774 - Loc: X=-9154.808 Y=520.339 Z=3874.939

00:07:07.707 - Crossed Checkpoint Door_CDeck_Cabin

00:07:07.774 - Loc: X=-9288.099 Y=524.376 Z=3874.939

00:07:07.941 - Stop Moving

00:07:08.774 - Loc: X=-9309.114 Y=525.012 Z=3874.939

00:07:08.774 - Rot: -99.368881

00:07:09.774 - Rot: -94.190735

00:07:09.940 - Start Moving

00:07:10.774 - Loc: X=-9318.961 Y=425.023 Z=3874.939

00:07:10.774 - Rot: -97.690582

00:07:10.974 - Stop Moving

00:07:11.774 - Loc: X=-9316.890 Y=405.301 Z=3874.939

00:07:11.774 - Rot: -80.857666

00:07:12.740 - Start Moving

00:07:12.773 - Loc: X=-9316.941 Y=404.781 Z=3874.939

00:07:12.773 - Rot: -95.852989

00:07:13.774 - Loc: X=-9299.591 Y=275.616 Z=3874.939

00:07:14.724 - Stop Moving

00:07:14.774 - Loc: X=-9299.319 Y=154.976 Z=3874.939

00:07:14.774 - Rot: -107.438881

00:07:15.707 - Start Moving

00:07:15.774 - Loc: X=-9299.313 Y=152.414 Z=3874.939

00:07:15.774 - Rot: -89.848541

00:07:16.057 - Stop Moving

00:07:16.707 - Start Moving

00:07:16.774 - Loc: X=-9296.715 Y=120.162 Z=3874.939

00:07:16.774 - Rot: -109.346458

00:07:17.774 - Loc: X=-9296.506 Y=3.587 Z=3874.939

00:07:17.774 - Rot: -98.502449

00:07:18.774 - Loc: X=-9294.224 Y=-106.198 Z=3874.939

00:07:19.773 - Loc: X=-9293.062 Y=-220.950 Z=3874.939

00:07:20.773 - Loc: X=-9293.050 Y=-347.014 Z=3874.939

00:07:21.773 - Loc: X=-9293.676 Y=-473.673 Z=3874.939

00:07:22.773 - Loc: X=-9293.048 Y=-600.774 Z=3874.939

00:07:23.190 - Stop Moving

00:07:23.773 - Loc: X=-9293.048 Y=-649.851 Z=3874.939

00:07:23.773 - Rot: -147.15596

00:07:24.406 - Start Moving

00:07:24.773 - Loc: X=-9293.016 Y=-694.089 Z=3874.939

00:07:24.973 - Stop Moving

00:07:25.773 - Loc: X=-9293.609 Y=-715.037 Z=3874.939

00:07:25.773 - Rot: -170.229034

00:07:29.773 - Rot: 135.019363

00:07:30.323 - Start Moving

00:07:30.773 - Loc: X=-9293.013 Y=-660.660 Z=3874.939

00:07:30.773 - Rot: 79.346588

00:07:31.773 - Loc: X=-9311.570 Y=-529.624 Z=3874.939

00:07:31.773 - Rot: 93.181931

00:07:32.773 - Loc: X=-9336.075 Y=-399.769 Z=3874.939

00:07:32.773 - Rot: 75.914413

00:07:33.773 - Loc: X=-9334.551 Y=-266.444 Z=3874.939

00:07:34.773 - Loc: X=-9333.026 Y=-133.121 Z=3874.939

00:07:35.773 - Loc: X=-9331.504 Y=0.171 Z=3874.939

00:07:36.773 - Loc: X=-9329.980 Y=133.536 Z=3874.939

00:07:37.773 - Loc: X=-9328.456 Y=266.828 Z=3874.939

00:07:37.807 - Alarm State Change: Prepare to Abandon Platform Alarm

00:07:38.773 - Loc: X=-9326.933 Y=400.165 Z=3874.939

00:07:39.773 - Loc: X=-9325.409 Y=533.482 Z=3874.939

00:07:40.673 - Stop Moving

00:07:40.773 - Loc: X=-9324.373 Y=649.445 Z=3874.939

00:07:41.774 - Rot: 129.875977

00:07:41.973 - Start Moving

00:07:42.774 - Stop Moving

00:07:42.774 - Loc: X=-9387.100 Y=725.104 Z=3874.939

00:07:42.774 - Rot: 133.094482

00:07:43.774 - Rot: -178.864975

00:07:44.474 - Start Moving

00:07:44.774 - Loc: X=-9421.681 Y=722.811 Z=3874.939

00:07:44.774 - Rot: -175.846375

00:07:45.124 - Crossed Checkpoint C-Deck_Hallway_StbdWing

00:07:45.774 - Loc: X=-9553.945 Y=729.241 Z=3874.939

00:07:45.774 - Rot: -179.89624

00:07:46.774 - Loc: X=-9686.867 Y=719.151 Z=3874.939

00:07:46.774 - Rot: -176.818268

00:07:47.774 - Loc: X=-9820.085 Y=719.150 Z=3874.939

00:07:47.774 - Rot: 174.86171

00:07:48.774 - Loc: X=-9952.073 Y=712.610 Z=3874.939

00:07:48.824 - Stop Moving

00:07:49.774 - Loc: X=-9955.267 Y=712.610 Z=3874.939

00:07:55.274 - Open Door_CDeck_ExternalRStbd1

00:07:55.940 - Start Moving

00:07:56.774 - Loc: X=-10057.531 Y=712.607 Z=3874.939

00:07:56.924 - Crossed Checkpoint Door_CDeck_ExternalRStbd1

00:07:57.491 - Open Door_CDeck_ExternalRStbd2

00:07:57.524 - Stop Moving

00:07:57.774 - Loc: X=-10152.805 Y=712.607 Z=3874.939

00:07:58.773 - Rot: -71.052734

00:07:59.574 - Close Door_CDeck_ExternalRStbd1

00:07:59.774 - Rot: 8.206528

00:07:59.807 - Start Moving

00:08:00.507 - Crossed Checkpoint Door_CDeck_ExternalRStbd2

00:08:00.774 - Loc: X=-10277.155 Y=705.663 Z=3875.301

00:08:01.124 - Stop Moving

00:08:01.174 - Close Door_CDeck_ExternalRStbd2

00:08:01.773 - Loc: X=-10320.960 Y=700.688 Z=3875.301

00:08:01.773 - Rot: -29.255747

00:08:02.374 - Start Moving

00:08:02.773 - Loc: X=-10314.292 Y=652.643 Z=3875.301

00:08:02.773 - Rot: -93.061844

00:08:03.773 - Loc: X=-10293.059 Y=521.047 Z=3875.301

00:08:04.773 - Loc: X=-10298.413 Y=391.829 Z=3875.301

00:08:04.773 - Rot: -127.073395

00:08:05.773 - Loc: X=-10353.911 Y=270.643 Z=3875.301

00:08:06.773 - Loc: X=-10409.427 Y=149.440 Z=3875.301

00:08:07.773 - Loc: X=-10427.253 Y=22.151 Z=3875.301

00:08:07.773 - Rot: -92.503029

00:08:08.773 - Loc: X=-10403.076 Y=-108.957 Z=3875.301

00:08:09.773 - Loc: X=-10375.670 Y=-236.673 Z=3875.308

00:08:09.773 - Rot: -55.097027

00:08:10.773 - Loc: X=-10270.761 Y=-209.166 Z=3875.308

00:08:10.773 - Rot: 69.951553

00:08:11.773 - Loc: X=-10265.245 Y=-98.241 Z=3839.000

00:08:11.773 - Rot: 76.66507

00:08:12.207 - Crossed Checkpoint C-Deck_Stairs_Outdoor_Down

00:08:12.774 - Loc: X=-10265.069 Y=-13.738 Z=3735.809

00:08:13.773 - Loc: X=-10264.902 Y=70.720 Z=3632.674

00:08:13.773 - Rot: 76.66507

00:08:14.340 - Crossed Checkpoint B-Deck_Stairs_Outdoor_Up

00:08:14.773 - Loc: X=-10264.782 Y=155.150 Z=3529.572

00:08:14.773 - Rot: 76.66507

00:08:15.774 - Loc: X=-10289.812 Y=278.877 Z=3527.821

00:08:15.774 - Rot: 135.995316

00:08:16.773 - Loc: X=-10409.481 Y=249.715 Z=3527.821

00:08:16.773 - Rot: -145.259125

00:08:17.773 - Loc: X=-10422.877 Y=122.785 Z=3527.821

00:08:17.773 - Rot: -97.10836

00:08:18.773 - Loc: X=-10408.643 Y=-9.803 Z=3527.821

00:08:19.773 - Loc: X=-10403.735 Y=-142.370 Z=3527.821

00:08:20.773 - Loc: X=-10363.001 Y=-261.600 Z=3527.821

00:08:20.773 - Rot: -33.269684

00:08:21.779 - Loc: X=-10275.572 Y=-196.076 Z=3527.821

00:08:21.779 - Rot: 82.279343

00:08:22.773 - Loc: X=-10291.669 Y=-89.479 Z=3473.847

00:08:22.773 - Rot: 88.527832

00:08:23.106 - Crossed Checkpoint B-Deck_Stairs_Outdoor_Down

00:08:23.773 - Loc: X=-10309.021 Y=-6.587 Z=3370.883

00:08:24.773 - Loc: X=-10326.366 Y=76.280 Z=3267.951

00:08:25.190 - Crossed Checkpoint A-Deck_Stairs_Outdoor_Up

00:08:25.773 - Loc: X=-10331.070 Y=196.918 Z=3175.402

00:08:25.773 - Rot: 81.910522

00:08:26.773 - Loc: X=-10343.167 Y=329.681 Z=3175.402

00:08:27.773 - Loc: X=-10355.000 Y=462.376 Z=3175.402

00:08:28.773 - Loc: X=-10366.521 Y=595.021 Z=3175.402

00:08:29.773 - Loc: X=-10378.044 Y=727.629 Z=3175.402

00:08:30.773 - Loc: X=-10389.576 Y=860.259 Z=3175.402

00:08:31.772 - Loc: X=-10401.088 Y=992.914 Z=3175.402

00:08:32.772 - Loc: X=-10430.453 Y=1121.114 Z=3175.402

00:08:32.772 - Rot: 102.186661

00:08:32.789 - Complete Route Outside to LB 1

00:08:32.789 - Crossed Checkpoint A-Deck_Alley_Stbd

00:08:33.772 - Loc: X=-10476.310 Y=1245.791 Z=3175.402

00:08:33.772 - Rot: 92.054077

00:08:34.772 - Loc: X=-10511.188 Y=1374.442 Z=3175.402

00:08:35.772 - Loc: X=-10536.938 Y=1504.368 Z=3175.402

00:08:35.772 - Rot: 74.420975

00:08:36.772 - Loc: X=-10527.025 Y=1636.978 Z=3175.402

00:08:36.772 - Rot: 63.141693

00:08:37.773 - Loc: X=-10428.792 Y=1694.773 Z=3175.402

00:08:37.773 - Rot: -23.879219

00:08:38.773 - Loc: X=-10302.909 Y=1659.527 Z=3175.402

00:08:39.773 - Loc: X=-10172.103 Y=1639.034 Z=3175.402

00:08:39.773 - Rot: 7.511217

00:08:40.772 - Loc: X=-10122.086 Y=1750.818 Z=3175.402

00:08:40.772 - Rot: 73.15937

00:08:41.656 - Open Container_MusterCab_C_3

00:08:41.773 - Loc: X=-10046.414 Y=1852.095 Z=3175.405

00:08:41.773 - Rot: 24.143757

00:08:41.923 - Stop Moving

00:08:42.206 - Start Moving

00:08:42.473 - Stop Moving

00:08:42.772 - Loc: X=-10033.475 Y=1859.211 Z=3175.405

00:08:42.772 - Rot: 35.593384

00:08:43.773 - Rot: 54.252552

00:08:44.539 - Open Menu MusterBoard

00:08:44.539 - Look at Starboard Lifeboat Musterboard

00:08:44.539 - This is your MusterBoard

00:08:44.773 - Rot: 53.513348

00:08:45.773 - Rot: 30.992538

00:08:46.773 - Rot: 33.450768

00:08:47.773 - Rot: 75.217865

00:08:48.773 - Rot: 72.154984

00:08:49.773 - Rot: 72.629387

00:08:50.773 - Rot: 72.629387

00:08:51.173 - Trying to Muster onto an existing TCard

00:08:52.773 - Rot: 72.967125

00:08:52.789 - Trying to Muster onto an existing TCard

00:08:53.773 - Rot: 54.172943

00:08:54.772 - Rot: 54.172943

00:08:55.772 - Rot: 76.337479

00:08:56.005 - Successful Muster at Lifeboat Station

00:08:56.772 - Rot: 50.436871

00:08:57.522 - Close Menu MusterBoard

00:08:57.772 - Rot: 52.904404

00:08:58.506 - Close Container_MusterCab_C_3

00:08:58.772 - Rot: 78.986855

00:08:59.772 - Rot: -175.934525

00:09:00.206 - Start Moving

00:09:00.772 - Loc: X=-9990.040 Y=1812.642 Z=3175.405

00:09:00.772 - Rot: -120.318871

00:09:01.773 - Loc: X=-9969.227 Y=1713.268 Z=3175.405

00:09:01.773 - Rot: -156.899338

00:09:02.772 - Loc: X=-10085.826 Y=1671.775 Z=3175.405

00:09:02.772 - Rot: -161.068481

00:09:03.606 - Stop Moving

00:09:03.772 - Loc: X=-10189.963 Y=1636.717 Z=3175.405

00:09:03.772 - Rot: 164.622437

00:09:04.322 - Start Moving

00:09:04.773 - Loc: X=-10239.651 Y=1651.523 Z=3175.405

00:09:04.773 - Rot: 125.883766

00:09:04.872 - Stop Moving

00:09:05.772 - Loc: X=-10249.840 Y=1656.630 Z=3175.405

00:09:05.772 - Rot: 130.854202

00:09:06.772 - Rot: 77.451897

00:09:07.772 - Rot: 77.451897

00:09:09.739 - Start Moving

00:09:09.772 - Loc: X=-10251.237 Y=1656.661 Z=3175.405

00:09:09.772 - Rot: 176.891815

00:09:10.772 - Loc: X=-10383.278 Y=1653.924 Z=3175.405

00:09:10.855 - Stop Moving

00:09:11.772 - Loc: X=-10392.590 Y=1653.661 Z=3175.405

00:09:11.772 - Rot: 77.729401

00:09:13.205 - Start Moving

00:09:13.655 - Stop Moving

00:09:13.772 - Loc: X=-10442.229 Y=1632.713 Z=3175.405

00:09:13.772 - Rot: 115.749649

00:09:14.772 - Rot: 73.953079

00:09:18.772 - Rot: 73.589127

00:09:19.772 - Rot: -15.463758

00:09:21.773 - Rot: -5.454593

00:09:21.939 - Start Moving

00:09:22.773 - Loc: X=-10338.092 Y=1622.770 Z=3175.405

00:09:23.490 - Stop Moving

00:09:23.773 - Loc: X=-10245.439 Y=1614.995 Z=3175.405

00:09:23.773 - Rot: 30.711359

00:09:24.306 - Start Moving

00:09:24.773 - Loc: X=-10240.521 Y=1670.826 Z=3175.405

00:09:24.773 - Rot: 84.958443

00:09:25.756 - Stop Moving

00:09:25.772 - Loc: X=-10223.723 Y=1795.844 Z=3175.405

00:09:26.772 - Rot: 169.149506

00:09:27.774 - Rot: -65.71254

00:09:27.807 - Start Moving

00:09:28.773 - Loc: X=-10164.125 Y=1690.409 Z=3175.405

00:09:28.773 - Rot: -65.789604

00:09:28.789 - Stop Moving

00:09:29.573 - Start Moving

00:09:29.773 - Loc: X=-10165.315 Y=1687.676 Z=3175.405

00:09:29.773 - Rot: -141.712524

00:09:30.772 - Loc: X=-10283.473 Y=1634.831 Z=3175.405

00:09:31.772 - Loc: X=-10386.479 Y=1619.979 Z=3175.402

00:09:31.772 - Rot: 144.788467

00:09:32.088 - Stop Moving

00:09:32.722 - Start Moving

00:09:32.772 - Loc: X=-10407.598 Y=1630.800 Z=3175.402

00:09:32.772 - Rot: 95.014671

00:09:33.105 - Stop Moving

00:09:33.772 - Loc: X=-10411.379 Y=1627.073 Z=3175.402

00:09:34.772 - Rot: 107.449593

00:09:34.872 - Start Moving

00:09:35.205 - Stop Moving

00:09:35.772 - Loc: X=-10422.651 Y=1662.938 Z=3175.402

00:09:35.772 - Rot: 103.469917

00:09:36.772 - Rot: 97.02636

00:09:41.772 - Rot: 93.622284

00:09:42.773 - Rot: 20.542034

00:09:43.773 - Rot: 2.200256

00:09:44.090 - Start Moving

00:09:44.773 - Loc: X=-10337.126 Y=1666.224 Z=3175.402

00:09:44.773 - Rot: 2.200256

00:09:45.773 - Loc: X=-10207.066 Y=1658.568 Z=3175.402

00:09:46.772 - Loc: X=-10073.902 Y=1663.686 Z=3175.402

00:09:47.772 - Loc: X=-9940.684 Y=1668.803 Z=3175.402

00:09:48.772 - Loc: X=-9807.431 Y=1673.923 Z=3175.402

00:09:49.772 - Loc: X=-9674.187 Y=1679.041 Z=3175.402

00:09:49.856 - Stop Moving

00:09:50.772 - Loc: X=-9667.227 Y=1679.308 Z=3175.402

00:09:50.772 - Rot: -71.846588

00:09:51.772 - Rot: -71.584801

00:09:52.772 - Rot: -145.168854

00:09:53.005 - Start Moving

00:09:53.772 - Loc: X=-9763.155 Y=1670.829 Z=3175.402

00:09:53.772 - Rot: -174.952774

00:09:54.773 - Loc: X=-9895.992 Y=1659.098 Z=3175.402

00:09:55.772 - Loc: X=-10028.781 Y=1647.371 Z=3175.402

00:09:56.771 - Loc: X=-10161.533 Y=1635.648 Z=3175.402

00:09:57.771 - Loc: X=-10294.275 Y=1623.924 Z=3175.402

00:09:58.554 - Stop Moving

00:09:58.771 - Loc: X=-10391.074 Y=1620.861 Z=3175.402

00:09:58.771 - Rot: 157.987457

00:09:59.371 - Start Moving

00:09:59.771 - Loc: X=-10409.264 Y=1665.376 Z=3175.402

00:09:59.771 - Rot: 112.231194

00:09:59.921 - Stop Moving

00:10:00.371 - Start Moving

00:10:00.771 - Loc: X=-10435.922 Y=1639.576 Z=3175.402

00:10:00.771 - Rot: 88.244057

00:10:00.955 - Stop Moving

00:10:01.771 - Loc: X=-10444.041 Y=1622.007 Z=3175.402

00:10:01.771 - Rot: 88.244057

00:10:01.871 - Start Moving

00:10:02.321 - Stop Moving

00:10:02.771 - Loc: X=-10442.448 Y=1673.826 Z=3175.402

00:10:02.771 - Rot: 72.923843

00:10:02.905 - Start Moving

00:10:03.238 - Stop Moving

00:10:03.771 - Loc: X=-10431.012 Y=1700.043 Z=3175.402

00:10:04.771 - Rot: 91.897011

00:10:05.771 - Rot: 94.67617

00:10:06.771 - Rot: 94.828682

00:10:12.771 - Rot: 62.648048

00:10:13.771 - Rot: 154.384659

00:10:14.772 - Rot: 41.170879

00:10:15.656 - Start Moving

00:10:15.772 - Loc: X=-10421.037 Y=1698.135 Z=3175.402

00:10:15.772 - Rot: -10.828707

00:10:16.739 - Stop Moving

00:10:16.772 - Loc: X=-10306.075 Y=1660.912 Z=3175.402

00:10:17.522 - Start Moving

00:10:17.772 - Loc: X=-10280.583 Y=1656.074 Z=3175.402

00:10:17.772 - Rot: 17.305218

00:10:18.772 - Loc: X=-10152.897 Y=1693.935 Z=3175.402

00:10:18.772 - Rot: 15.76903

00:10:19.771 - Loc: X=-10021.787 Y=1678.737 Z=3175.402

00:10:19.771 - Rot: -10.745543

00:10:20.771 - Loc: X=-9888.964 Y=1684.569 Z=3175.402

00:10:20.771 - Rot: 4.452965

00:10:21.771 - Loc: X=-9756.021 Y=1694.921 Z=3175.402

00:10:22.771 - Loc: X=-9623.115 Y=1705.270 Z=3175.402

00:10:23.771 - Loc: X=-9490.192 Y=1715.620 Z=3175.402

00:10:24.771 - Loc: X=-9357.293 Y=1725.969 Z=3175.402

00:10:25.771 - Loc: X=-9224.360 Y=1736.321 Z=3175.402

00:10:26.771 - Loc: X=-9091.472 Y=1746.669 Z=3175.402

00:10:27.738 - Stop Moving

00:10:27.771 - Loc: X=-8984.043 Y=1689.207 Z=3175.402

00:10:27.771 - Rot: -60.654999

00:10:28.288 - Start Moving

00:10:28.655 - Stop Moving

00:10:28.771 - Loc: X=-8940.690 Y=1686.348 Z=3175.402

00:10:28.771 - Rot: -66.340202

00:10:29.055 - Start Moving

00:10:29.371 - Stop Moving

00:10:29.771 - Loc: X=-8913.238 Y=1696.610 Z=3175.402

00:10:29.771 - Rot: -42.756481

00:10:31.072 - Start Moving

00:10:31.405 - Stop Moving

00:10:31.771 - Loc: X=-8898.892 Y=1669.517 Z=3175.405

00:10:31.771 - Rot: -47.554272

00:10:32.772 - Rot: -137.398529

00:10:33.772 - Rot: -179.848877

00:10:33.905 - Start Moving

00:10:34.772 - Loc: X=-9005.063 Y=1703.063 Z=3175.405

00:10:34.772 - Rot: 161.435745

00:10:35.555 - Stop Moving

00:10:35.773 - Loc: X=-9102.648 Y=1719.392 Z=3175.405

00:10:35.773 - Rot: -153.114624

00:10:36.172 - Start Moving

00:10:36.772 - Loc: X=-9119.952 Y=1679.543 Z=3175.405

00:10:36.772 - Rot: -114.248383

00:10:37.773 - Loc: X=-9179.886 Y=1566.499 Z=3175.405

00:10:37.922 - Stop Moving

00:10:38.422 - Start Moving

00:10:38.772 - Loc: X=-9184.587 Y=1594.718 Z=3175.405

00:10:38.772 - Rot: -91.856697

00:10:38.922 - Stop Moving

00:10:39.755 - Start Moving

00:10:39.772 - Loc: X=-9184.024 Y=1612.137 Z=3175.405

00:10:40.088 - Stop Moving

00:10:40.772 - Loc: X=-9185.254 Y=1574.212 Z=3175.405

00:10:53.671 - Start Moving

00:10:53.771 - Loc: X=-9191.984 Y=1575.715 Z=3175.405

00:10:53.771 - Rot: 167.409775

00:10:54.771 - Loc: X=-9321.054 Y=1604.265 Z=3175.405

00:10:54.788 - Stop Moving

00:10:56.738 - Start Moving

00:10:56.771 - Loc: X=-9322.616 Y=1604.498 Z=3175.405

00:10:57.771 - Loc: X=-9449.921 Y=1631.899 Z=3175.405

00:10:58.771 - Loc: X=-9583.204 Y=1634.624 Z=3175.405

00:10:59.771 - Loc: X=-9714.654 Y=1643.974 Z=3175.405

00:11:00.771 - Loc: X=-9847.981 Y=1644.247 Z=3175.405

00:11:01.770 - Loc: X=-9981.281 Y=1643.887 Z=3175.405

00:11:02.770 - Loc: X=-10114.544 Y=1641.011 Z=3175.405

00:11:03.770 - Loc: X=-10247.764 Y=1636.980 Z=3175.405

00:11:03.836 - Stop Moving

00:11:04.770 - Loc: X=-10257.422 Y=1635.749 Z=3175.405

00:11:04.770 - Rot: 90.725922

00:11:05.453 - Start Moving

00:11:05.770 - Loc: X=-10293.725 Y=1624.890 Z=3175.405

00:11:05.770 - Rot: 151.738693

00:11:06.719 - Stop Moving

00:11:06.769 - Loc: X=-10387.102 Y=1619.130 Z=3175.402

00:11:06.769 - Rot: 130.8862

00:11:07.770 - Rot: 45.968422

00:11:08.137 - Start Moving

00:11:08.770 - Loc: X=-10308.293 Y=1618.466 Z=3175.401

00:11:08.770 - Rot: -3.119074

00:11:09.770 - Loc: X=-10176.844 Y=1634.591 Z=3175.401

00:11:09.770 - Rot: 12.454356

00:11:10.769 - Loc: X=-10045.061 Y=1639.293 Z=3175.401

00:11:10.769 - Rot: -5.881835

00:11:11.769 - Loc: X=-9913.236 Y=1642.833 Z=3175.401

00:11:11.769 - Rot: 12.817306

00:11:12.770 - Loc: X=-9783.215 Y=1672.416 Z=3175.401

00:11:13.770 - Loc: X=-9651.501 Y=1687.125 Z=3175.401

00:11:13.770 - Rot: -0.818093

00:11:14.770 - Loc: X=-9520.661 Y=1664.839 Z=3175.401

00:11:14.770 - Rot: -16.204311

00:11:15.770 - Loc: X=-9389.951 Y=1644.256 Z=3175.401

00:11:15.770 - Rot: 7.465348

00:11:16.769 - Loc: X=-9306.669 Y=1744.507 Z=3175.401

00:11:16.769 - Rot: 42.606674

00:11:17.003 - Stop Moving

00:11:17.771 - Loc: X=-9291.685 Y=1768.688 Z=3175.401

00:11:17.771 - Rot: -73.072105

00:11:17.837 - Start Moving

00:11:18.771 - Loc: X=-9268.562 Y=1652.000 Z=3175.401

00:11:18.771 - Rot: -79.328445

00:11:19.121 - Stop Moving

00:11:19.421 - Start Moving

00:11:19.771 - Loc: X=-9243.142 Y=1569.103 Z=3175.401

00:11:19.788 - Stop Moving

00:11:20.755 - Start Moving

00:11:20.771 - Loc: X=-9242.948 Y=1568.031 Z=3175.401

00:11:20.771 - Rot: -78.47612

00:11:21.354 - Stop Moving

00:11:21.771 - Loc: X=-9251.312 Y=1639.094 Z=3175.401

00:11:21.771 - Rot: -78.47612

00:11:22.371 - Start Moving

00:11:22.604 - Stop Moving

00:11:22.771 - Loc: X=-9246.053 Y=1613.579 Z=3175.401

00:11:22.771 - Rot: -72.204048

00:11:22.938 - Start Moving

00:11:23.121 - Stop Moving

00:11:23.771 - Loc: X=-9240.152 Y=1595.215 Z=3175.401

00:11:28.772 - Rot: -87.261017

00:11:29.772 - Rot: -72.130615

00:11:29.938 - Item Success: Grab Bag

00:11:29.938 - Item: Open Grab Bag

00:11:30.921 - Gained a Flashlight

00:11:31.671 - Item Success: Survival Suit

00:11:31.671 - Item: Put on Survival Suit

00:11:31.938 - Gained a Smoke Hood

00:11:32.772 - Rot: -152.019272

00:11:33.671 - Costume change complete

00:11:33.688 - Start Moving

00:11:33.771 - Loc: X=-9249.981 Y=1597.427 Z=3175.401

00:11:33.771 - Rot: 167.318695

00:11:34.104 - Stop Moving

00:11:34.405 - Start Moving

00:11:34.588 - Stop Moving

00:11:34.771 - Loc: X=-9309.869 Y=1610.562 Z=3175.401

00:11:35.221 - Start Moving

00:11:35.771 - Loc: X=-9378.559 Y=1626.017 Z=3175.401

00:11:36.771 - Loc: X=-9510.246 Y=1646.531 Z=3175.401

00:11:37.771 - Loc: X=-9642.930 Y=1659.308 Z=3175.401

00:11:38.772 - Loc: X=-9776.225 Y=1663.234 Z=3175.401

00:11:39.172 - Alarm State Change: Alarm Off

00:11:39.772 - Loc: X=-9832.813 Y=1663.896 Z=3175.401

00:14:15.969 - ----------

00:14:15.969 - Total Doors Still Open: 0

00:14:15.969 - Total Doors Still Open Percentage: 0.0%

00:14:15.969 - Total Running Time: 0.0s

00:14:15.969 - Total Running Time Percentage: 0.0%

00:14:15.969 - Total Hazard Time: 0.0s

00:14:15.969 - Total Hazard Time Percentage: 0.0%

00:14:15.969 - End Scenario