Emotionally resonant videos with virtual reality exercises in contractor safety training

by

Richard Hannah

B.A., Texas A&M University, 1997
M.B.A., University of Phoenix, 2005

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Education
College of Educational Leadership

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Manhattan, Kansas

2024

Abstract

The purpose of this research was to investigate the effects of virtual reality (VR) and emotionally resonant videos on knowledge retention for adult learners at a contractor safety training organization supporting the energy industry. The intent of this research was to determine if traditional computer-based training (CBT) can be made more effective with the addition of VR exercises with emotionally resonant videos. The two experimental groups were exposed to either CBTs augmented by VR exercises that reinforced the CBT course learning objectives and included work-relevant videos designed to arouse an emotional response or CBTs with VR exercises without videos. The control group for this research took the same CBT course without VR exercises and without videos. A quantitative analysis was performed on data collected from a follow-up quiz delivered three days after the completion of the course(s). Data from this follow-up quiz was analyzed to determine if there was greater knowledge retention of the course learning objectives and procedures among the experimental groups than among the control group. The results found a non-statistically significant relationship between the groups, however, trends between the groups show that there are benefits for transfer of learning when using VR and VR with emotionally resonant videos compared to those groups without these tools. Additionally, a deeper analysis of the results, when considering aspects of the participants' demographic and experience variables, suggests that the recall quiz results may have been affected by an increased cognitive load on younger and inexperienced participants.

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Approved by:

Major Professor
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Chapter 1 - Introduction

Despite improvements in safety and health training for the energy industry and construction trades that support the energy industry, key indicators used to gauge contractor safety have remained level since 2015. According to the U.S. Department of Labor (DOL), Bureau of Labor Statistics (BLS), severe violations in safe work practices and procedures that lead to injuries or fatalities continue to occur in the energy industry and construction trades that support the industry. The energy and construction industries continue to face significant challenges to the health and safety of their operator and contractor workforce, even though the industries have a safety record that is better than average among all industries tracked by the BLS (U.S. Department of Labor, Bureau of Labor Statistics [BLS], 2022a). Safety metrics have not improved despite innovations in tooling and improvements in safe work practices and procedures. This could indicate that these industries have exhausted all possible capabilities to effectively address and counter-act hazardous issues however, it could also indicate increasing complacency within the workforce or poorly designed or insufficient training. Finding ways to improve contractor worker safety training could help mitigate safety incidents for workers who are exposed to potentially injurious or fatal hazards at jobsites.

The United States Occupational Safety and Health Administration (OSHA) provides training and compliance standards for organizations that support the energy industry, for workers who enter the energy industry, and for workers already working in the industry. OSHA's training standards have lessened the likelihood of severe safety incidents and decreased injury and fatality incident rates since the introduction of the Process Safety Management (PSM) standards in 1992. However, improvements in training are necessary to continue to drive incident rates down and protect workers.

According to the BLS (2022b), the energy industry onboards over 300,000 new employees every year, and the construction industry accounts for almost 11 million workers in the U.S. workforce. Following the effects of the COVID-19 pandemic in 2019 and 2020, that number is expected to rise again to pre-pandemic levels that approach 12 million workers (Gallagher, 2022). In 2020, total recordable cases for the construction industry, a number that represents injuries in the industry per 100 full-time workers, reached a total recordable incidence rate (TRIR) of 2.5 (BLS, 2022a). This includes much of the work done by contractors in the energy industry. Although a TRIR of 2.5 is lower than the national average among other industries, this number includes 1,034 fatalities within the energy industry, an overall increase from previous years. In 2021, there were 798 worker fatalities caused by exposure to harmful substances or environments, the highest total number of U.S. worker fatalities since 2011, an 18.8% increase from the previous year (BLS, 2022c). If the energy industry expects to gain almost 400,000 new jobs by 2030 in construction-related trades this increase would mean a greater number of full-time workers being exposed to these potentially fatal jobsite hazards (BLS, 2022b).

Production facilities in the energy industry are challenging workplaces with many more hazards that must be mitigated than in workplaces in industries without jobsite hazards. Refineries, chemical plants, and other similar facilities routinely handle large quantities of highly hazardous chemicals and process materials that are held under pressure and at high temperatures (OSHA, 2022a). A single failure anywhere in the system could be catastrophic (Barab, 2010). In these hazardous work environments, personnel or systems failures can be devastating to other workers, the environment, and the communities surrounding these jobsites.

Jobsite accidents in the energy industry can lead to injuries, fires, explosions, damage to equipment, toxic environmental releases, and fatalities. Every worker has a part to play in maintaining safety standards and preventing mishaps and disasters. New workers entering the industry must be trained and integrated into existing work teams quickly and must understand both the dangers of the work they perform and the hazards they will face on the jobsite. Experienced workers need to keep up to date on changes to processes and procedures through annual refresher training, and they must be retrained as conditions on the jobsite merit. The potential for accidents and incidents can be mitigated in part through effective training for experienced workers and new employees alike.

One hazardous work scope that can lead to injuries or fatalities for workers in the energy industry is work that includes operating in and around confined spaces. According to OSHA (2022b), confined spaces are workplaces that are: (a) large enough for a worker to enter, (b) difficult to enter or exit, and (c) not designed for continuous habitation. One example of a confined space is a permit-required confined space, which meets all of the above characteristics with the added risk that it may become lethal due to the presence of atmospheric hazards or potential for engulfment. According to the BLS (2022d), between 2011 and 2018, there were 1,030 confined space fatalities.

One of the more recent confined space fatalities in the energy industry occurred in 2022 and affected not just the site owner but the contractors who were a part of the work crews for the project (California Occupational Safety and Health Association [Cal/OSHA], 2022). Exposure to harmful substances or environments, a classification for permit-required confined space work and hazards, led to more worker fatalities in 2021 than in 2020 and the highest number of fatalities in this category for the past ten years (BLS, 2022c).

Although great strides have been made in improving worker safety training when working in and around confined spaces, there are still opportunities to better prepare energy industry contractors who work around these dangerous work environments. OSHA mandates that contractors who support the energy industry must receive initial training and annual refresher training on confined space dangers and safe work practices (OSHA, 2015). Most of this training is delivered through computer-based training (CBT) and is only occasionally accompanied by hands-on training (Grant, 2022). Because CBT is the prevalent delivery method for these and other OSHA-mandated new hire and refresher training courses, identifying more effective CBT delivery techniques for confined space training could lead to improved safety metrics and increased safety for employees entering and working in and around confined spaces (Business and Industry Connection [BIC], 2022a).

Background of the Study

Contractor organizations that support the energy industry have seasonal work demands that require hiring a large number of workers in a short period of time (BIC, 2022b) with high turnover rates (Awan & Anjam, 2015; Harhara et al., 2015; Majidadi et al., 2015). The turnover rates and constant influx of new employees add to the industry's need for safe work standards and efficient, effective safety training. Despite their lack of experience, new workers can often find themselves in risky environments, including working in or monitoring confined spaces. In some cases, the newest employees on the work teams are specifically tasked with safety roles like Hole Watch or Confined Space Attendant, both of which require an intimate understanding of the dangers, risk mitigation procedures, and emergency procedures associated with confined space work. This dynamic creates a disparity between the workers' experience and the severity of risks and hazards that these workers must protect themselves and others against.

Safety skills training and safety compliance training for contractors in the energy industry have traditionally been provided using CBTs that leverage computer terminals at safety councils near jobsites. This style of training has several key advantages. It is scalable, allows easy verification of the learner's identity, provides the opportunity to train large numbers of temporary or new workers to a set standard, and ensures consistency and compliance (BIC, 2022a). However, for training to be effective, the learner must be able to remember procedures and safety information in the field, not just while taking training. This transfer of learning, described by Bossard et al. (2008) as the ability of the learner to use the skills and knowledge learned in training in a work environment, has historically not been a focus for CBT training for contractor organizations that support the energy industry. Instead, an emphasis has been placed on speedy onboarding and course completion. Even so, spending more time on training is not always the most cost-effective method of training delivery, nor is it worthwhile for organizations to spend time on training that does not effectively facilitate the transfer of learning. Finding solutions that allow for the transfer of learning objectives quickly yet effectively to influence safer work practices when working in or around confined spaces should be a goal of safety training institutes and training leaders within the energy industry.

A study of work practices in petrochemical plants that included both virtual reality (VR) training and non-VR training showed that learners who completed training in an immersive VR environment identified open valves correctly at a rate 25% greater than their non-VR-trained counterparts (Colombo et al., 2014). The same study by Colombo et al. showed that learners trained using immersive VR simulations responded to and stopped leaks in a simulated virtual petrochemical plant environment 42% faster than others, resulting in smaller spills.

In 2020, several safety councils in the Gulf Coast region of the Southern United States released CBT courses with VR exercises. One safety council found through an internal study that participants who took CBT courses augmented with VR exercises had higher scores on follow-up exams administered one week after course completion (Health and Safety Council [HASC], 2020). Other industries are starting to see reductions in both training costs and training time using VR as a training tool (Bailenson, 2020; Holm, 2021; Xie et al., 2021). Despite this and other studies that show a record of success for VR in improving safe work practices and stimulating the transfer of learning in a variety of industries, very few energy industry contractor organizations use VR as a standard training tool.

Due to past reliance on CBT training delivery, energy contractors have little to no experience with courses delivered via VR. Additionally, the hazardous nature of confined space work requires that VR courses be tailored in such a way that deliberate, effective transfer of learning occurs following the VR course delivery. Integrating VR into the standard course delivery systems and optimizing VR training effectiveness has the potential to improve the transfer of knowledge, retention of information, and learning. This study investigated the effects of CBTs augmented with emotionally resonant, job-relevant videos combined with VR exercises. The successful completion of this study provides new insights into training techniques that can empower contractors to navigate hazardous work environments safely and ultimately lower the rate of mishaps and accidents in the energy industry.

Problem Statement

Research shows that emotion can be leveraged in training to enhance the encoding and durability of memories of learning objectives (Brown, 2014; Diemer et al., 2015; Marín-Morales et al., 2018; Sousa, 2006; Tyng et al., 2017). The problem this study investigated is whether the possibility of transfer of learning from the training area to the jobsite could be augmented or improved by emotionally resonant videos that are added to VR exercises within CBTs as measured by recall tests provided three days after training. Transfer of learning, or the ability to apply knowledge and skills in a work environment, is the end goal of contractor safety and skills training. Although CBT courses can be quickly developed, are scalable, and are capable of reporting OSHA-required safety training compliance metrics; the courses and the delivery methods may not help learners absorb and retain information or recall it when they return to the jobsite. Additionally, following initial compliance training, many new hires are not offered opportunities for continued training and learning which would reinforce their earlier training (Remisio & El-Farmaoui, 2008; Wengroff, 2019).

Studies have shown that providing CBTs that engage the learner and allow the opportunity for the learner to practice, reflect, and simulate real-world experiences in VR leads to more durable memory development (Boller et al., 2021; Bossard et al., 2008; Kamińska et al., 2020; Knörzer et al., 2016). VR training courses with the addition of cueing mechanisms such as multisensory cues, greater simulation fidelity, visual-auditory fidelity, or other factors that increase realism have been proven to make VR training more successful than those without these capabilities (Cooper et al., 2021; Rinalducci, 1996). Few studies show what effect VR exercises combined with the addition of emotion cues integrated into CBTs.

Purpose of the Research

The purpose of this study is to investigate the effects of VR training with emotionally resonant videos on the transfer of learning for contractors who work in the energy industry. Although numerous studies show the effectiveness of VR training in a variety of industries, few studies focus on VR exercises with emotionally resonant videos for energy industry contractors.

The results of this study provide results that can improve safety training for contractors who work at sites that include hazardous permit-required confined spaces.

This study investigated the differences between learner recall for participants who completed traditional CBTs and those who completed CBTs augmented with VR and emotionally resonant videos or those who completed CBTs augmented with VR exercises with no emotionally resonant videos. This study offers other training professionals and researchers information that could lead to future improvements to worker safety and community safety in and around hazardous jobsites.

Conceptual Framework

VR exercises that are augmented with emotionally resonant videos provide an opportunity to create more durable memories by leveraging constructivist learning theories, cognitivist learning theories, and several tangential, complementary concepts.

Constructivist learning theories are founded on the idea that learners construct new meaning from previous experiences and then follow those experiences up with reflection to gain understanding (Fenwick, 2004; Kolb, 1984; Merriam & Bierema, 2014). Another basic tenet of constructivism is that learners create personal meaning from their experiences and build on prior learning and existing information (Knowles et al., 2012). Many scholars differentiate between cognitive constructivism, based on principles formulated by the work of Piaget, and social constructivism, based on principles formulated by Vygotsky (Marin et al., 2000; Powell & Kalina, 2009) when discussing constructivist learning theories. This study has a particular focus on concepts found in cognitive constructivist learning theories. As Powell and Kalina (2009) write:

> In cognitive constructivism, ideas are constructed in individuals through a personal process, as opposed to social constructivism where ideas are constructed through interaction with the teacher and other students. While they are fundamentally different both types will ultimately form overall constructivism or constructed learning elements for students to easily grasp; the main concept being that ideas are constructed from experience to have a personal meaning for the student. (p. 241)

For the purposes of explaining the concepts used within this study, the term constructivism should be taken to coincide with cognitive constructivist learning theories, while cognitivism in this study will focus on the overall processes and systems used for developing, organizing, processing, and accessing memory by adult learners. Driscoll (2005) writes of cognitivism and memory research that "when learning occurs, information is input from the environment, processed and stored in memory, and output in the form of some learned capability" (p. 74). Merriam and Bierema (2014) explain that this process of memory development begins as information is provided to the learner via their senses and processed from the environment within which it is gathered.

McHaney et al. (2018) contend that a central concept of both constructivist and cognitivist learning involves active learning through simulations. In addition, they explain that simulation training activates aspects of the learners' cognitive capabilities to learn via active learning, reflective practice, experiential learning, and knowledge building, including repetition, and reinforcement training. As Zapalska et al. (2012) state:

> Active learning with simulations and games enables students to actively experiment, test and apply what they have learned in other and more complex situations. The goal is to let

> students experience something new and then encourage reflection about their experience. (p. 164)

Many studies show the benefit of learning through simulation training and active learning and discuss the effectiveness of simulations for linking knowledge and theory to application (Mabry et al., 2020; Moskaliuk et al., 2013; Pantelidis, 2009).

Simulations in VR can provide multiple representations of reality in realistic digital environments. Liaw (2004) notes that constructivist learning environments (CLE) and web-based environments promote constructivist learning by offering multiple possible representations of the real world and allow for knowledge construction, not just reproduction. Simulations provide the opportunity for learning tasks and procedures in a real-world context, as well as for encouraging reflection. As Driscoll (2005) writes regarding multiple recall studies, "Results indicated that recall was best for those who were instructed and tested in the same situation" (p. 102) within which they learned the information. Simulations with mixed media evolve e-learning from a linear model to one in which the learner plays a more active role, understands that role, and reflects on the role and the learning (Iverson & Colkey, 2004).

Another key concept within constructivist and cognitivist adult learning theories according to Fenwick (2001) and Taylor and Marienau (2016) is experiential learning. Dewey (1938) explains in *Experience and Education* that, "every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (p. 35). In their work, Schott and Marshall (2018) discuss how simulations that rely on experiential learning frameworks follow Kolb's Learning Cycle by stating that "Action creates an experience, which is followed by reflection on both the action and the experience, which in turn triggers abstractions from the reflection, and ultimately new application of the abstraction" (p.

844). Kolb's learning cycle allows learners to move from (a) concrete experience to (b) observations and reflection followed by, (c) formation of abstract concepts and moves to (d) testing these concepts in new situations, before starting the cycle again. Experiences, even simulated experiences, allow learners the opportunity to follow Kolb's learning cycle. They let learners interact with an environment, have the experience reinforced through reflection, and allow simulated experiences to shape future experiences.

A subsidiary concept used in this study includes evoking emotion during learning sessions to provide additional memory retrieval cues, thereby enhancing memory durability. Dirkx (2001) and Dirkx (2006) explain that emotion, whether the adult learner is conscious of it or not, plays an integral part in the meaning-making aspects of constructivist learning approaches and experiential learning. Similarly, emotion can aid in the development of stronger memories following cognitivist learning theories. Emotion, especially emotion that is enhanced by an immersive learning environment, creates a more diverse memory trace during memory development and as Brown (2014) writes, adds more memory cues for later retrieval. Studies have shown that more diverse and realistic learning environments lead to greater memory durability (Cooper et al., 2021; Schott & Marshall, 2018). The introduction of emotional experiences into the learning environment can motivate learners to understand what they learn in a deeper more meaningful way, and potentially engender a transformative learning experience as shown by various studies on VR, immersive learning, and transformative learning (Cowin, 2021; Marín-Morales et al., 2020; Nelson, 2009; Tyng et al., 2017).

Narrative storytelling can also play a role in developing more memory retrieval cues for adult learners. The concept of narrative transportation mixes emotion, greater engagement, increased immersiveness, and the opportunity for learners to take action following the story.

There is evidence that learning through storytelling provides more accurate recollection after the learning takes place (Boris, 2017). Researchers have also found that training that uses stories in many cases is remembered longer and more clearly. Rossiter (2002) writes of narrative and story being a fundamental aspect of human communication in that it allows learners a greater opportunity to provide meaning and understand context. While, Zak (2015), in his research on the neurochemical effects of emotional storytelling, found that participants in his study who were provided emotional stories were more likely to engage and cooperate with others and become more pro-social.

The goal of leveraging these techniques and technologies is to help learners develop durable memory and inspire greater transfer of learning. Transfer of learning, put simply is the opportunity for adult learners to utilize knowledge learned in training in non-training situations. The ability of adult learners to apply their training site learning to the jobsite is at the heart of the transfer of learning (Haskell, 2000; Steiner, 2001). Haskell (2004) discusses transfer of learning in terms of experiences and stresses that new experiences are built onto the frameworks or templates that the adult learner has already built from previous experience. Haskell (2004) emphasizes experience, and the adult learner's ability to build on previous experience for all levels of transfer of learning including application transfer, context transfer, and near transfer.

This study was designed to investigate how applying the above concepts via technological delivery systems of CBTs augmented with VR exercises and emotionally resonant videos affects the opportunity for greater transfer of learning. The VR exercises used for this study leverage techniques that allow adult learners to practice and experience a simulation while developing new meaning through those experiences and by building onto their prior or existing knowledge. The emotionally resonant videos, narrative storytelling, and immersive virtual environment were used to heighten the engagement level of the learner. Three days after the study participants were exposed to the new training and completed all of the course work, the participants were quizzed to determine recall. Participants who took the more immersive courses, one enhanced by VR and emotionally resonant videos, or by just VR, were hypothesized to have higher test scores than those who only completed CBT training.

Research Question

The objective of this research was to investigate the difference between the experimental treatment groups' performance three days following course completion as compared to the performance of the control group with the same delay. To do this, this study investigated the relationship between learner knowledge retention of confined space safety awareness material using CBT with VR or CBT with VR exercises and emotionally resonant videos compared to learners without the opportunity to take these. The following research question guided the researcher in examining the differences in memory durability for participants who completed the confined space courses:

- Do differences exist in knowledge retention for contractors from the following three groups: those who completed confined space courses with VR and emotionally resonant videos, those who took confined space courses with VR, and those who completed confined space courses without VR and without emotionally resonant videos?

This study tested the following hypotheses based on the research question:

Hypothesis

In order to help answer the research questions, it's best to have both a null hypothesis and and alternative hypothesis. These are used to help prove or disprove the research question (Creswell, 2013). The null hypothesis for this study was:

> Ho. There is no difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

The alternative hypothesis for this study way:

> Ha. There is a difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

Research Method

This study followed an experimental research design using quantitative data analysis with an independent variable. This research design is classified as a randomized multiple treatments design and a control group with a post-test-only design (Bridgmon & Martin, 2013; Creswell, 2013). This design included three important aspects of experimental research including: (a) random assignment, (b) the opportunity to include a control group, and (c) the chance to manipulate an independent variable.

Three separate groups of learners demonstrated the effects of the study's independent variable:

- The first treatment consisted of the confined space CBT with VR exercises augmented with emotionally resonant videos that reinforced course objectives.
- The second treatment included the confined space CBT with VR exercises without emotionally resonant videos.
- The control group included learners who took the confined space CBT without VR exercises and without emotionally resonant videos.

A follow-up quiz provided three days after the completion of the course acted as the post-test measurement instrument to determine the durability of each learner's memory. The data acquired from the learner's responses was used to analyze the potential impact VR exercises augmented with emotional videos, or VR exercises alone, have on learner retention and memory durability of procedures and course information.

The sample for this study included energy industry contractors who work in the Gulf Coast region of the Southern United States and visited a safety council to take the safety council's confined space awareness course. Learners who were assigned to the control group took the course without VR exercises and emotional videos during the study time period, while learners who were assigned to the experimental groups took the CBT with VR exercises and emotionally resonant videos or the CBT with only VR exercises. The CBT course in each group contained the same material presented in the same manner and style, except for the addition or absence of VR exercises and emotionally resonant videos.

Post-test data collection quizzes were delivered via short message service (SMS) technology in the form of a follow-up quiz three days after course completion and included five questions. These questions were designed by the primary researcher to measure knowledge retention in an unbiased manner. The questions were designed so that a learner from any of the three groups could answer them, and did not bias one course over another. The three-day delay was in line with other studies that have measured VR knowledge retention (Bréchet et al., 2019; Kamińska et al., 2020; Karpicke & Roediger, 2008). The scores generated from the follow-up quiz were analyzed to determine how each group performed. This research builds on similar studies that have been performed by VR researchers except that this study integrated immersive VR exercises and videos into the CBT courses and included emotional elements (Corriveau Lecavalier et al., 2020; Kamińska et al., 2020; Madden et al., 2020; Pantelidis, 2009; Parong & Mayer, 2018).

Significance of the Study

Although numerous studies show the effectiveness of VR training, few studies apply emotion to VR through storytelling techniques and measure the knowledge retention or durability of memory against traditional training methods. Additionally, there are very few studies that focus on how VR training, much less VR training with emotionally resonant videos can be applied within the community of contract workers that support the energy industry. Although there are studies on industrial refinery owner operators and VR training efficacy (Colombo et al., 2014; Gavish et al., 2015; Vasilevski & Birt, 2020), there is a gap in the research on how VR training affects contractors and how VR training that elicits emotion for the learner can encourage more durable memories. The results can be used to improve worker safety and community safety in and around jobsites that include hazardous characteristics like those found in the energy industries. Finally, the results could potentially be useful to industries beyond the energy sector that also rely on CBT training delivery.

Limitations/Delimitations of the Study

The test subjects were limited to contractors in the energy and construction trades who support the energy industry and who were trained in confined space awareness at a single safety council in the Gulf Coast region of the Southern United States. The general assumption regarding this research is that all participants, no matter which course they took, answered the quiz questions truthfully and to the best of their abilities. Additionally, it is assumed that the participants took the training course(s) seriously with the intent to learn and remember the skills, policies, procedures, and objectives that were a part of that course. It is assumed that all participants, no matter the course they took experienced similar learning outcomes so that the follow-up quiz delivered three days after the completion of the course(s) could be compared.

Some of the limitations of this research include the fact that participants who took the training came from a variety of different contracting organizations and possessed different skills and training backgrounds. Within the sample were contractors who may have never completed confined space awareness training and contractors who had taken similar training or worked in and around confined space jobsites for many years. Additionally, there are different training requirements that the various organizations impose on their employees that might occur after participants complete this study's courses and before the delivery of the follow-up quiz. This might have impacted the results and analysis, but these differences should have been overcome by the research design that ensured a random sample from the population.

Another limitation of this study includes the fact that the sample was composed of participants trained at a single safety council. Many contractors in the energy industry, especially experienced contractors, have a deep understanding of confined space policies and procedures. Contractors who support manufacturing, traditional construction, or other industries may not have similar scores as the contractors tested within this study. This study's quantitative research design focused on an analysis of memory durability and knowledge retention regarding the objectives, policies, and procedures that are part of a confined space awareness course for contractors who support the energy industry in the Gulf Coast Region of the United States. Caution should be taken in making broad generalizations about the entire industry or other industries.

An additional limitation of this study deals with the number of non-native English speakers who participated. During a recent internal safety council survey, 30% of the total survey population at the safety council completing one course were non-native English speakers. The majority of the safety council's courses are written, developed, and delivered for contractors who speak and understand English. Although a non-native English-speaking study participant might understand the policies, procedures, and objectives that are a part of the course, it is possible that a participant within this study with no working knowledge of the English language might take the course and guess the answers sufficiently to pass the course. This study was not able to assess the language proficiency of participants before they took the course(s).

A final limitation of this study is the participant's responses to the follow-up quiz administered three days following the course(s) completion. The follow-up quiz was delivered via SMS text directly to the participant's smartphones. Each participant was asked to complete the follow-up quiz, but completion was not required by the safety council, nor did OSHA and the participating contractor organizations mandate the completion of the follow-up quiz. Additionally, only participants who had smartphones were able to access and complete the follow-up quiz. This limitation could have resulted in fewer participants completing the follow-up quiz than completing the CBT course but did not undermine the strength of the experimental design.

To keep the follow-up quiz design simple for users, the follow-up quiz questions were limited to multiple-choice and true/false questions with only one correct answer per question. Past internal studies performed by safety councils have found that follow-up quizzes with more than five questions have yielded fewer returned results from participants. This study limited the number of questions to five in the hopes of gathering as much data as possible from the sample following the three-day delay. Additionally, the questions were limited to multiple choice and true/false questions as past studies have found that few learners are motivated to provide answers to open-ended questions.

The potential for bias also exists in participant selection and consent. People more comfortable with technology may be more likely to participate in a VR study and agree to consent. The study was promoted to the participants as an opportunity to help the safety council tailor learning to better meet the needs of the learning community that they serve. Therefore, those participants who may not be comfortable working and training at the safety council, or who may not see themselves as long-term workers within the community, might not have felt compelled to consent to be a part of the study. Many of these learners might have not consented because few if any studies are performed by the safety council on a regular basis. As such, the potential that subjective bias was introduced in the participant selection process exists.

The study's limitations also extend to the methodology and limitations of the sample size. As it is purely quantitative, this study's limitations include a narrow data set using a pre-set array of variables which limits the depth of analysis. While there was a sufficient sized sample to exclude sub-groups and provide a deeper analysis in some cases, there were sub-groups with too few participants to perform a thoughtful and thorough analysis. For example, analyzing how females performed compared to males was impossible due to the few number of females who consented to be a part of the study. Lastly, the analysis did not include any qualitative variables. Feelings of frustration toward the technology or understanding participants' lack of knowledge using the hardware could impact participants' ability to learn and, therefore, their recall quiz scores and the results of this study.

The answers that participants provided regarding their experience with VR in both their personal and training lives, show that a large majority of the participants had no previous experience with this technology. According to the experience variable information collected during this study, 97% of the study's participants indicated that they had no previous experience with VR. Results from the groups might be challenged by the fact that so many participants had no previous VR experience and were forced to not only learn information on confined space awareness but also learn how to use the VR equipment and interact with the simulated environment. This lack of experience with one aspect of the course delivery could have affected the opportunity for the participants to encode and process memory from the course effectively.

The proposed study did not include a comparative analysis of the confined space course(s) and other courses that were available at other safety councils but limited the research and analysis to the specific confined space courses described in this proposal. Finally, this study was designed to only analyze participants' memory durability around the confined space awareness course(s) over a three-day period.

Definitions of Terms

Table 1.1. Definitions and Acronyms Used for this Study

Term	Acronym	Definition
Computer-Based Training	CBT	The acronym for the delivery method of providing training through a computer terminal.
Confined Space	CS	The abbreviation for a confined space awareness CBT course used for this study. This course does not include VR exercises or emotionally resonant videos.
Confined Space and Virtual Reality	CS-VR	The abbreviation for a confined space awareness CBT course with VR exercises used for this study. This course does not include emotionally resonant videos.
Confined Space, Virtual Reality, and Video	CS-VR-V	The abbreviation for a confined space awareness CBT course with VR exercises and emotionally resonant videos used for this study.
Follow-Up Quiz	-	A quiz delivered via SMS text messaging technology that provides learners the opportunity to answer quiz questions and allows the safety council to track quiz scores.
Learning Management System	LMS	The acronym for learning management system. An LMS is usually a database designed to register, track, and deliver CBT training courses.
Short Messaging Service	SMS	The acronym for short messaging service. The delivery mechanism for the follow-up quiz used in this study.
Virtual Reality	VR	The acronym for virtual reality; VR is a 3D, immersive technology that provides interactive simulations for learners.

Summary

This chapter discussed the purpose and significance of research that could improve safety training for contractors in the energy industry, including training for hazardous environments like activities performed in permit-required confined spaces. The research questions are designed to determine if using VR exercises alone or using emotional videos with VR exercises can optimize the use of CBTs for contractor learners who deal with these hazardous work scopes in the energy industry. The conceptual framework expressed in this chapter reviews constructivist and cognitivist learning theories and how emotion, storytelling, immersive VR, and practice via simulation can contribute to more durable memories for learners. Finally, this chapter revealed the strength of the quantitative research design and gave an overview of the data that will be collected from the SMS follow-up quiz scheduled for delivery three days after course completion.

Chapter 2 - Review of Related Literature

VR training and VR studies have been carried out for decades, and still, there are varied results about how practical VR training is compared to traditional training styles. Additionally, there is no consensus on how VR training can be optimized to help adult learners understand and retain information. Although there are many facets to explore in the area of VR training, this study will focus on the use of emotionally resonant videos with VR exercises to determine if these tools create more durable memories for learners who take CBTs. The central question posed when reviewing past research in preparation for this study was: how can VR exercises with emotionally resonant videos integrated into CBT courses affect memory development and retrieval for contractors in the energy industry? This chapter contains a review of related literature that examines: (a) the use of VR in safety training education, (b) the methods that VR uses for making memories, (c) the ability of VR and video to promote emotional arousal, (d) how emotion can affect memory, and (e) opportunities to develop more durable memories through narrative storytelling.

Background

A single safety council can provide over one million training courses a year to contractors working in the energy industry. In 2022, a contractor safety council in the Gulf Coast region of the Southern United States provided over 50,000 confined space courses to the contractor community it supports. Despite this high volume of training and courses provided by other councils, training centers, and organizations, there have been more than 100 confined space-related fatalities every year since 2013. Between 2011 and 2018, Texas supported by safety councils in the Gulf Coast region of the Southern United States, had the most confined space fatalities among all other states (BLS, 2022c). Finding ways to improve the effectiveness of confined space CBTs could potentially decrease the number of confined space safety incidents in the Gulf Coast and in other regions (Wallen & Mulloy, 2005).

Many safety and compliance training courses are provided to contractors via CBTs at safety councils throughout the United States. Although hands-on training and instructor-led training might be perceived as more effective (Bhoir & Esmaeili, 2015), CBTs are more scalable, easy to access and edit, and have been a part of contractor training in the energy industry for decades (BIC, 2022a). Safety councils can employ various methods to influence greater learner engagement and produce more long-lasting memories for adult learners when developing CBTs. These methods include job-relevant videos, interactive slides, animations, case studies, reflective moments, and VR exercises (Lee et al., 2000). Integrating VR with emotionally resonant videos into CBT courses could further optimize the effectiveness of CBT courses.

Safety councils primarily train adult learners. Adult learning principles are designed with the unique characteristics of adult learners in mind. According to Ross-Gordon et al. (2017) two aspects that make adult learners unique, and that the proposed study intends to leverage are: (a) adult learners' reservoir of deep experiences to which they can relate to learning and (b) a need to apply learning to current life conditions, or a desire for relevance or meaning. Ross-Gordon et al. explain that:

> Adults' prior knowledge and past experiences influence the focus, motivation, and processing of knowledge and skills. It also assumes that adults are not passive, but rather active learners who value authentic experience learning, and problem-posing strategies related to their current life conditions. (p. 220)

Taylor et al. (2000) address this uniqueness of adult learners desiring relevance and applying experience by writing: "Whether building on something they already know or exploring new areas, adults want to learn things that seem relevant and applicable to their current lives" (p. 4).

This study used VR simulations to help learners utilize their previous experiences and build on them. For more lasting learning to occur, however, adults need a reflective opportunity as well (Kolb, 1984; Knowles et al., 2012). In the case of simulations, according to Hertel and Mills (2002), adults need a chance to debrief after the simulation. They write "The simulation debriefing as well as interactions throughout the simulation provide the legitimization necessary to bring the students to a new state of knowledge and experience" (Hertel & Mills, 2002, p. 7). This debriefing, or the opportunity to reflect is provided to learners in the proposed study through the use of emotionally resonant videos. Regarding adult learners, Fenwick (2004) notes the following:

> Learning happens only when there is reflective thought and internal processing of that experience by learning, in a way that actively makes sense of the experience, that links the experience to previous learning, and that transforms the learner's previous understanding in some way. (p. 47)

This opportunity to leverage adult learners' previous experience and allow them to reflect and analyze their actions and experiences or make that experience relevant or meaningful is unique to adult learners' needs and is a central concept within this research.

According to Brown (2014), durable memories are those that learners consolidate from short-term memory to long-term memory either through reinforcement mechanisms or by creating a variety of cueing mechanisms. When writing about durable memory, Brown writes that providing cues that allow learners to retrieve information acquired during training is an underutilized method for durable memory development and future retrieval of information. This information retrieval, especially when the setting where the information must be applied differs however slightly from the learning environment, is the essence of the transfer of learning. This study investigated how training with VR and emotion can improve the opportunity for transfer of learning when coursework is conducted at a training facility and then remembered by contractors once they return to the jobsite.

Bossard et al. (2008) paraphrasing Presseau and Frenay (2004), state that the "transfer of learning is, broadly speaking, a process in which knowledge constructed in a particular context (source task) is used in a different context (target task) after being mobilized, recombined and/or adapted" (p. 1). Transfer of learning is critical for workers who may be exposed to hazards at jobsites immediately following their training. Safety information and procedures about hazardous work, like those used when working around confined spaces, must be recalled by workers, especially when there may be an emergency situation.

VR and Safety Training

Although VR simulations and exercises are an established training tool for safety training and skills training in a variety of industries there are questions about how effective it is, or what tools can be utilized to make them more effective for learners. Over the last few decades, many studies have explored the use of VR as a safety training tool for highly procedural-related tasks such as military training or police force training (Bertram et al., 2015; Giessing, 2021; Moore et al., 2019; Moskaliuk et al., 2013; Siu et al., 2016; Vogel-Walcutt et al., 2011; Webster, 2016; Wright, 2013), for hazardous jobsite and safety training (Bhoir & Esmaeili, 2015; Gallagher et al., 2013; Sankaranarayanan et al., 2018; Tanaka et al., 2015), in emergency preparedness for wildfires (Hoang et al., 2010), emergency rescue training, earthquake rescue and mass casualty event training (Li et al., 2005; Li et al., 2017; Lowe et al., 2020), in emergency action plan training in industrial plants (Longo et al., 2019), or industrial maintenance tasks (Colombo et al., 2014; Gavish et al., 2015; Juricic et al., 2015; Patle et al., 2019).

Safety training using VR simulations has two main strengths. First, it can provide learners the opportunity to practice high-risk procedures in a safe, simulated, realistic environment. It can also help make complex and complicated training more accessible for learners. This can be seen in a multitude of studies. In her study, Pantelidis (2009) points out that in VR simulations learners can be put into situations and have the opportunity to practice procedures and actions in situations that would be dangerous in real life without sacrificing safety. Mellet-d'Huart (2009) concludes through a review of VR, that VR provides opportunities to expand education into lifelong learning through simulations and practice. Hamilton et al. (2021) find that VR "conferred a learning benefit in around half of the cognitive studies, especially where highly complex or conceptual problems required spatial understanding and visualization" (p. 26) and that procedural tasks were learned best in VR. This same benefit for spatial understanding for the learner using VR was found in Jensen and Konradsen's (2018) review of VR head-mounted displays (HMD).

As VR technology improves and becomes more accessible, VR studies have focused on how virtual simulations can be optimized to provide greater training effectiveness using greater presence, immersiveness, and embodiment (Jensen & Konradsen, 2018; Marín-Morales et al., 2020), how VR simulations can create an opportunity for greater self-efficacy for learners (Mabry et al., 2020), and in what ways VR courses can enhance learner motivation (Bertram et al., 2015; Moskaliuk et al., 2013). Several studies investigate how to optimize VR using multisensory cueing methods such as using distinct smells, or tactile feedback

(Cooper et al., 2021; Herz, 2021; Rinalducci, 1996), and acceptance of VR as a training technology (Noble et al., 2022; Surendran, 2012).

In recent years VR courses have become more commonplace in safety training for energy-producing owners and operators but have not become as ubiquitous for contractor training. Many studies and articles discuss how VR training is being used by large energy industry corporations (American Fuel and Petrochemical Manufacturers [AFPM], 2020; Benedict, 2019; Taylor, 2022), while Colombo et al. (2014) and Juricic et al. (2015) focus on how VR technology simulators have been used to improve the health and safety of industrial plant operators. Contactors must work with and around the same dangers as energy production site owners and operators who are already taking advantage of VR as a training tool. The same benefits that owners and operators gain through VR courses can be leveraged for contractors who service and maintain the energy production sites.

Many of the above-referenced studies provide not only evidence of the efficacy of simulation training but also provide evidence of VR effectiveness in increasing the likelihood of transfer of learning. Transfer of learning is the ability of the learner to apply knowledge learned in training to other experiences (Haskell, 2004; Steiner, 2001). Many studies show evidence that VR simulations as part of a safety training system can increase the opportunity to transfer learning objectives. Studies such as Mabry et al. (2020) found that VR-trained students "not only performed more effectively in simulations, but anecdotal observations of clinical educators were that students were better prepared for clinical practice" (p. 204) after the training. Work by Pedram et al. (2021), as well as Perez et al. (2013) focusing on VR simulator training for the mining industry, concluded that VR not only helps learners overcome real-world training hazards and constraints but also better equips the learner for real-world situations.

VR and Memory Making

VR courses help create durable memories by activating different types of memory: semantic memory and episodic memory, as well as by working within both allocentric and egocentric frameworks. Duff et al. (2019) show that declarative memory is composed of semantic and episodic memories, while Tuena et al. (2019) demonstrate that semantic memory, or the ability to recall words, concepts, or numbers, and episodic memory, or the ability to remember an event, are two types of memory that VR affects. Tuena et al. also provide evidence of a link between spatial cognition and episodic memory by showing that using body motion to create memory cues and signals from the learner in VR leads to more durable memory-retrieval opportunities.

Allocentric frameworks, an object-to-object frame of reference or world-centered, and egocentric frameworks, a self-to-object frame of reference or self-centered, also play a part in creating more lasting memories in VR. As shown by Burgess et al. (2002) as well as Bird and Burgess (2008), activating memory-making platforms for both frameworks can create stronger memories. Burgess et al. in their study of the cognitive map theory and how the hippocampus supports allocentric processing, use VR simulations to activate memory coding in both egocentric and allocentric frameworks and show how more durable memories are created for study participants. Similarly, Tuena et al. (2019) also studying memory and the hippocampus, find that "the hippocampus provides the allocentric spatial scaffold for episodes binding neocortical representations of the event" (p. 2). Jeffery (2018) notes that head direction cells, place cells, and grid cells, all act as part of the memory-making capabilities within the hippocampus in VR environments and serve to stimulate this allocentric framework for learners.

Tuena et al. (2019) go further in their study to find that memory-making cells are all activated by input tools used in VR and that simulations designed to activate sensorimotor involvement and enhance enactment for spatial and episodic memory in turn yield more durable memories. Krokos et al. (2019) support this when discussing movement and speed in VR environments. They find that the more active a subject is when creating a memory, the more place cells, head-direction cells, grid cells, and sensorimotor cells that are used, and the more pathways that are activated in creating the memory, the stronger and more durable the memory becomes for the learner. Similarly, Gatlin (2014) reviews studies that show how place cells help to create a map or spatial framework that produces way-finder cues for later retrieval of the memory by the learner. This internal spatial mapping and navigation, which researchers call spatial cognition is a critical aspect of memory encoding according to studies by Harman et al. (2017), Eichenbaum (2017), and Schiller et al. (2015). In this model, the hippocampus works with the entorhinal cortex to encode memories using both egocentric and allocentric frameworks.

Another cognitivist concept at work with VR training is reinforcement through repetition. Hintzman and Block (1971) suggest that repetition creates stronger memories via the multiple-trace memory model. This same model can be applied to the practice session capabilities that VR exercises provide. Studies by Tuena et al. (2019), Jeffery (2018), and Krokos et al. (2019) all reinforce both constructivist and cognitivist learning principles as well as the multiple trace and memory cueing mechanism that VR inspires to make more durable memories. When more memory-making cells are activated during encoding in VR, and when there is the opportunity to practice, which strengthens the durability of the episodic memory, this gives the learner more retrieval paths for accessing information at a later time. As Brown (2014) suggests when writing about memory cues, if there is a diversity of memory cues, the cues provide learners a better opportunity to recall the learning at a later time and lead to a more robust transfer of learning for the learner. Studies by Cooper et al. (2021), Gallagher et al. (2013), and Allen et al. (1986) investigate the use of VR and simulators in terms of the effectiveness of transfer of learning through optimization of different aspects of VR fidelity and peripherals, all of which can be linked to the theory of adding more cue points for memory retrieval.

Studies like those by Hamilton et al. (2021) and Corriveau Lecavalier et al. (2020) show that practicing procedural tasks or processes in an immersive VR environment provides greater, more durable memories than those where learners did not use VR for training. Similarly, the study on immersive environments by Katz and Halpern (2015) found that a more immersive VR simulation led participants to want to perform the same actions in real life in much the same way they performed in simulations. There are a multitude of other studies that tend to show this same relationship between immersive VR environments and presence inspiring greater memory durability and transfer of learning (Bailey et al., 2012; Burgess et al., 2002; Nowak & Biocca, 2003) which justifies the proposed studies' use of 3D immersive simulations, covered in more detail in later sections of this chapter.

In most cases with research similar to this study, memory durability is measured by providing a gap between course completion and testing (Boller et al., 2021; Fassbender & Helden, 2006; Kamińska et al., 2020; Krokos et al., 2019). Krokos et al. provide a gap between course completion and testing of two minutes. The researchers support this by stating that "The information in the short-term memory decays and is lost within a period of 15–30 s [seconds]. We feel confident that having participants recall 21 faces after a 2-min break will engage their long-term memory" (Krokos et al., 2019, p. 7). They base this on work performed by Atkinson and Shiffrin (1968) when they write, "information in the short-term store decays completely and is lost within about 30 seconds" (p. 90). Driscoll (2005) reiterates this contention regarding the short-term memory store being only 20–30 seconds suggesting that when learners are conscious of memory and earnestly considering the ideas and learning they are keeping that information in a short-term or working memory store. Driscoll also contends that only those things that are deliberately reinforced, applied to existing knowledge, or made meaningful are processed into long-term memory. This research suggests that the amount of information transferred, how it is applied by the learner and attached to existing knowledge, and the importance the learner attaches to the information determines the length of time it stays with the learner's short-term memory store, and whether or not it is transferred to the long-term memory store.

Fassbender and Helden (2006) find that learners who developed memories via VR simulations, although not significantly improved immediately after the course, did have more significant recall one week following the training course. Kamińska et al. (2020) measure the memory encoding and durability of learning objectives in engineering students. They tested participants following a three-day gap to determine how the VR participants performed and found that VR participants scored an average of 25% higher on memory tests following a three-day gap than learners who did not have the advantage of taking the course via VR. In their study, Boller et al. (2021) used VR to assess and promote the transfer of learning in adults with memory challenges and find, following a one-week delay, that the VR condition improved recall. This process of providing a delay between course delivery and applying a measurement instrument to assess memory durability is well-founded in the above-referenced studies and has been replicated for this proposed study.

Several studies have found that cognitive load for participants increased in immersive virtual simulations to a point that it affects working memory and the ability of learners to process and develop durable memories (Breves & Stein, 2023; Chen et al., 2022; Juliano et al. 2022). Juliano et al. find that when using immersive HMD VR there was a decrease in long-term motor memory formation due to an increased cognitive load being placed on their participants. The results of their study show that cognitive load increased in their VR condition compared to the computer screen condition and led to poorer performance for participants in that VR condition. Fisher et al. (2019) find that within multimedia environments an increase in cognitive load results from variables such as learning new processes and procedures that must be remembered later and that cognitive load increased for participants irrespective of the media modality used. This implies that regardless of how the VR exercises and video are configured, there will be a higher cognitive load placed on the study participants.

According to Sweller et al. (2019), cognitive load is split into the three following categories: (a) intrinsic load, which is focused on the complexity of the information presented, (b) extraneous load, or how the information is presented, in this case using virtual elements, as well as visual and auditory elements, and (c) germane load, based on the learning that the participant must remember, which effects the working memory resources. This study will utilize a variety of methods including signaling, restricting the duration of the exercise, and limiting the complexity of the VR exercises, all techniques that have been shown through studies to help limit the opportunity for increasing cognitive load for VR participants (Albus et al., 2021; Breves & Stein, 2023; van Merriënboer & Sweller, 2005).

VR and Emotional Arousal

This study used VR and emotional arousal to increase the chance that learners would develop more durable memory. The application of emotion to training can enhance memory development and increase the chance for memory retrieval, an aspect of this study that will be described in more detail in later sections. In terms of VR delivery, there is ample evidence that utilizing an immersive system like VR can potentially increase the emotion learners experience (Kim et al., 2014; Marín-Morales et al., 2019; Marín-Morales et al., 2020).

A key component of VR fidelity is immersiveness, which is the feeling of being present in an online or virtual environment as brought about by sensory fidelity and a sense of realism (Basu, 2019). According to Mayer (2020), Barsom et al. (2020), Krokos et al. (2019), and Corriveau Lecavalier et al. (2020), a learner's sense of presence and feeling of immersiveness is higher in 3D simulations than in 2D versions of the same simulations. Linking immersiveness to memory durability, Parong and Mayer (2018) find that participants trained with 3D VR scored higher in their follow-up exams than participants trained in the 2D condition. Not only do Parong and Mayer support the idea that immersive simulations are more beneficial for durable memory formation than non-immersive, but they also argue that the cycle of action and reflection at the heart of constructivist learning theory is a pivotal part of VR learning. The work by Schöne et al. (2019) supports the work by Parong and Mayer by studying the effectiveness of 3D immersive VR compared to flat 2D versions of the same material. Their study finds that 3D immersive VR conditions provide more durable, broad-based, event memory than 2D conditions.

Pallavicini et al. (2019) studying immersive VR environments show that immersive 3D VR environments inspire more significant emotional responses from learners than 2D versions of the same material. They find that "players showed a more intense emotional response, as assessed with a self-report questionnaire and with psycho-physiological indexes (heart rate and skin conductance), after playing in virtual reality versus after playing through the desktop display" (Pallavicini et al., 2019, p. 152). Marín-Morales et al. (2020) investigating how emotions affect learning in VR and find results that strongly suggest that immersive VR can revolutionize emotional arousal in commercial and research VR designs. Bujić et al. (2021) find in their investigation of VR and 360-degree video to inspire emotion, that VR evokes a greater emotional response than the written word. Many other studies on emotional arousal and VR immersive environments, tend to show that participants experience greater emotional arousal in immersive VR environments when compared to less immersive equivalents that include less presence (Ausburn & Ausburn, 2008; Bréchet et al., 2019; Diemer et al., 2015; Tian et al., 2021).

Marín-Morales et al. (2018) discovered both active and passive emotion elicitation in subjects, and that passive techniques that present images, videos, or sounds, can be utilized successfully, especially in a VR environment, to arouse emotion in learners. Their qualitative study shows that participants who experienced a virtual museum through VR reported higher valence and emotional arousal than participants who experienced a physical museum. However, these researchers find that the participants who experienced the physical museum showed greater emotional arousal than VR participants when providing a similar experiment using quantitative measurement tools such as heart-rate monitors (Marín-Morales et al., 2021). The authors confirm that while heart-rate monitors for VR participants measure less arousal, the VR participant's perceived emotional response is higher. In both cases and other studies tend to support, emotional arousal in VR is far greater than in 2D or non-VR presentations (Baños et al., 2004; Kim et al., 2014; Marín-Morales et al., 2020; Tian et al., 2021).

Taking this further, Allcoat and von Mühlenen (2018) find that participants in the VR condition of their study "showed better performance for 'remembering' than those in the traditional and the video conditions. Emotion self-ratings before and after the learning phase showed an increase in positive emotions and a decrease in negative emotions for the VR condition" (p. 1). The quantitative section of their study measures positive and negative emotional resonance across VR, textbook, or video conditions. They find that VR courses lead to a greater increase in positive emotions and a more significant decrease in negative emotions as compared to the two other conditions. Their results also show a significant increase in knowledge acquisition and retention for the VR participants compared to the non-VR participants.

Since immersive VR environments and simulations have been shown to heighten emotional states as well as inspire a greater sense of embodiment and presence, leading to greater episodic memory durability, this study used an immersive VR digital environment instead of a 2D condition to further investigate the impact of these techniques on knowledge retention.

Emotion and Memory Durability

Based on evidence that emotion is heightened in 3D immersive VR training, this study also leveraged emotion to enhance and optimize learning opportunities for the participants. Several studies show that emotional arousal for adult learners regardless of the learning delivery or environment can lead to greater memory durability (Anderson & Shimamura, 2005; Hamann et al., 1999; McGaugh, 2004; Vuilleumier, 2005). Additionally, many of these studies demonstrate that there is a link between memory encoding and durability with emotion type (Oatley & Johnson-Laird, 2014; Talmi, 2013; Um et al., 2012).

Holland and Kensinger (2010) write that adult learners are more likely to recall memories that are filled with emotions and note that experiences that are more relevant and personal are more likely to be remembered. According to Oatley and Johnson-Laird (2014) and Talmi (2013), emotions can enhance empathy and reasoning for adult learners and can help consolidate memory. Holland and Kensinger also discuss the fact that many researchers have found that memories associated with highly emotional moments are often easier to recall, even with long gaps of time between memory development and the recall event.

Studies like Brosch et al. (2013) and Kuriyama et al. (2010) provide positive evidence linking emotional memory and memory durability. Kuriyama et al. find that while the hippocampus is integral in the encoding of event memory, the amygdala is critical for emotional memory construction. Hamann et al. (1999), Phelps (2004), and McGaugh (2004), all find that the amygdala's role in memory development is greater than previously supposed because of the relationship of the system with emotion. Their studies show that emotional memories are better retained by participants than neutral ones at least in part because of the amygdala's work encoding emotional stimuli. Tyng et al. (2017) state:

> Substantial evidence has established that emotional events are remembered more clearly, accurately and for longer periods of time than are neutral events. Emotional memory enhancement appears to involve the integration of cognitive and emotional neural networks, in which activation of the amygdala enhances the processing of emotionally arousing stimuli while also modulating enhanced memory consolidation along with other memory-related brain regions, particularly the amygdala. (p. 17)

Writing about the effects of emotion and motivation on the transfer of learning, Haskell (2000) notes that "motivation, or more specifically, a spirit of transfer is a primary prerequisite for transfer to occur . . . without this affective or emotion/feeling-based foundation, the impetus to transfer is unlikely to occur" (p. 46). Bolstering this, Wolfe (2006) writes in his chapter on emotion in adult learning, that emotions provide motivation and aid memory making when added to simulations. Specifically, he states, "educators can use the power of emotion to affect learning and retention positively. Simulations, role plays, and other experiential activities can be highly engaging. By intensifying the student's emotional state, they may enhance both meaning and memory" (Wolfe, 2006, p. 39). Finally, Hirst and Phelps (2016) contend that the emotional-integrative model, a model that focuses on the effect of greater emotional arousal on flashbulb memories, can lead to memories that are naturally rehearsed by the learner leading to greater reinforcement and thereby greater memory durability.

Multiple studies promote eliciting positive emotions in training. Steffes and Duverger (2012) find that using humor, which has a positive valence, with videos had the potential to increase learner retention by 6%. Anderson and Shimamura (2005), drawing on cue utilization and emotional arousal while viewing videos, state that:

> Arousing film clips (car chase or ski jump film clips) enhanced context memory. This effect was not observed on the free recall test, which could suggest that arousal has particular effects on the association of central information to its context. Thus, for context memory, arousing film clips enhanced performance, whereas negatively valenced film clips reduced performance. (p. 331)

When and how to arouse emotions in the learner is a focus for Zlomuzica et al. (2016) and Knörzer et al. (2016) in their investigation of the Cognitive-Affective Theory of Learning with Media (CATLM), and Um et al. (2012) and Plass et al. (2014) and their work in using multimedia design. Knörzer et al. find that positive emotions before learning increase memory durability and that although a "learner's emotional state had a crucial impact on learning outcomes: learners with a negative emotional state before learning outperformed learners with a positive emotional state" (p. 627). This finding by Knörzer et al. confirms what Bujić et al. (2021) write regarding the emotional enhancement of memory (EEM) theory which states that memory is enhanced by emotion regardless of positive or negative valence. However, even Knörzer et al. admit that their results are not in line with previous experiences by Um et al. and Plass et al. who found positive results for learning from positive emotions.

Holland and Kensinger (2010) find in their study, that emotional arousal, irrespective of valence, positively impacts memory construction. Specifically, Holland and Kensinger conclude, that "the affective characteristics of an event can influence the likelihood that a memory is encoded, stored, and retrieved" (p. 36) and that "emotion affects the information that becomes a part of the memory trace as well as the information that is accessible for recall" (p. 36). To support the elicitation of emotion with positive valence Kuriyama et al. (2010) find that episodic memories are commonly misremembered when fear is a part of the memory encoding. However, in contrast to Kuriyama et al., Diemer et al. (2015) find that event memory is stronger when strong emotions, like fear, are present.

Storytelling and Memory

The idea that emotionally laden videos combined with VR inspire more durable memories is not only an aspect of multimedia design to drive greater engagement by the learner, researchers have also found a positive effect on memory when utilizing narrative storytelling and in determining the placement of videos in the training (Mar et al., 2021, Morris et al., 2019; Sun & Cheng, 2007, Zhao et al., 2011).

Storytelling and video storytelling build engagement and create emotional responses in the learner. Morris et al. (2019) studying engagement levels for participants in their work on narrative types state that "Across three experiments, we found that narratives framed as stories consistently outperformed factual narratives for encouraging action-taking in all audiences. We suggest that this is because they more effectively trigger autonomic reactivity and emotional arousal" (p. 31). In part, the authors state that this greater engagement toward action-taking and emotional arousal is inspired by narrative transportation which comes via greater immersion. Their study finds that greater narrative transportation comes through increased empathy for the characters in the study, and greater emotional arousal arises through narrative transportation.

Boris (2017) writes that "learning which stems from a well-told story is remembered more accurately and for far longer than learning derived from facts and figures" (para. 7). Additionally, Boris writes about the value of storytelling using case studies where learners are placed into the situation the story presents and are asked to imagine how they would have acted. Storytelling as a technique for providing richness to learners through the opportunity to create their own digital story is an established technique for both younger and adult learners (Baim, 2015; Rossiter, 2002; Sarıca & Usluel, 2016) but hearing a story or providing information in a narrative also provides benefits for knowledge retention.

Donkor (2010) and Donkor (2011) provide both qualitative and quantitative evidence that video instruction is superior to print-based material for online delivery methods. Rossiter (2002), paraphrasing Bruner (1986), Bruner (2002), and Polkinghorne (1988) adds that "narrative and story in adult education is an understanding of narrative as a broad orientation grounded in the premise that narrative is a fundamental structure of human meaning-making" (p. 2). This idea of meaning-making is addressed by Merriam (1993) when she writes "personal experiences are filtered through this meaning structure. A life experience congruent with the meaning structure is assimilated into the structure" (p. 85). Thus, meaning-making is critical in that it is linked to experience and the comprehension of the learning by the adult learner.

Mar et al. (2021) found in their research on storytelling and expository information recall that those participants who were asked to recall information through story were significantly more likely to remember information than those in the expository condition. The researchers state that "stories are more familiar than essays in many ways, including their resemblance to everyday experience, prevalence throughout human history, and precedence developmentally. In addition, stories are often more emotional than essays, and emotion can aid memory" (p. 733). Their metanalysis finds that people have an easier time comprehending and remembering information when it is presented in a narrative or story-telling format. They caution that their data is not conclusive, and that more data is necessary to confirm their findings, but evidence suggests there is a great deal of potential for narrative storytelling to work as a memory recall agent that could use the learner's prior experience and capture their imagination to motivate and engage.

Zhao et al. (2011), studying participants' responses to emotionally-driven storytelling, find that re-editing television footage, as this study also proposes, is an effective method for generating emotion. However, they also warn that video length can undermine engagement levels, as longer videos are not as effective as shorter videos. Zak (2015) in his research on the neurochemical effects of emotional storytelling found that participants in his study who were provided emotional stories were more likely to engage and cooperate with others and become more pro-social. His studies not only found that stories could elicit a greater sense of empathy from the receiver, but that many of the characteristics of captivating story-telling also lead to greater engagement by the listener, as well as increased motivation. Richardson et al. (2020) and Sun and Cheng (2007) speak to this sense of engagement when investigating differences in engagement levels between learners introduced to video and audio lessons. In these studies, adult learners self-reported greater engagement when shown video materials. These studies tend to show that story-telling, especially when a story is well told and concise, cannot only benefit the learner's memory but also help inspire engagement and empathy.

A majority of the research investigated for this study found that not only can narrative storytelling affect learners' memory but that there are benefits to the placement of videos when they are integrated into learning (Lee et al., 2000). Both the contiguity principle (Carmichael et al., 2018) and the temporal contiguity principle (Mayer, 2020) show that videos that are placed near the information they support allow for more effective essential cognitive processing (Clark & Mayer, 2016; Mayer, 2014). The videos developed to support this study were shown after the VR exercises and were created deliberately to exclude any intensive analysis of the activities or emotions that might be perceived as negative. Instead, the videos after the exercises were developed to engage the learner during encoding both due to placement in the course and through the emotion they elicit so the memory of the learning objectives might be recalled more easily at a later time.

Conceptual Framework

A key benefit of training in VR environments is that VR provides learners an opportunity to experience and practice potentially life-threatening or dangerous procedures in virtual simulations without fear of sustaining injuries or exposing themselves or others to hazards (Ernstsen et al., 2019; Pedram et al., 2021; Sankaranarayanan et al., 2018). By pairing emotionally resonant videos with VR exercises, this research hoped to optimize the use of VR exercises and the delivery of learning objectives to make memories developed during training more durable for contractors who utilize safety councils for training. This technique relies on adult learners actively working through simulations, experiencing realistic challenges in a safe environment, and reflecting on their actions. This framework, which is based on constructivist and cognitivist adult learning theories, allowed the safety council's adult learners the chance to develop more durable memories by allowing them to create more memory retrieval cues.

Within this study, the term constructivism coincides with cognitive constructivist learning theories. Cognitivism, for the purposes of this study, focuses on the processes and systems used for developing, organizing, processing, and accessing memory. Constructivist learning theories are based on the idea that new knowledge is constructed based on previous experience, activity learning, and experiences that allow the learner to reflect and learn through practice and rehearsal (Hertel & Mills, 2002; Knowles et al., 2012; Kolb, 1984). Cognitive constructivist learning theories specifically are built on the understanding that adult learners analyze, scaffold understanding based on their previous knowledge, and make new mental models based on problem-solving (Powell & Kalina, 2009; Ross-Gordon et al., 2017; Taylor et al., 2000). Applying these primary learning theories via a delivery model that is centered on CBT with VR and video storytelling provides the best opportunity for developing multiple retrieval cues and inspiring greater transfer of learning.

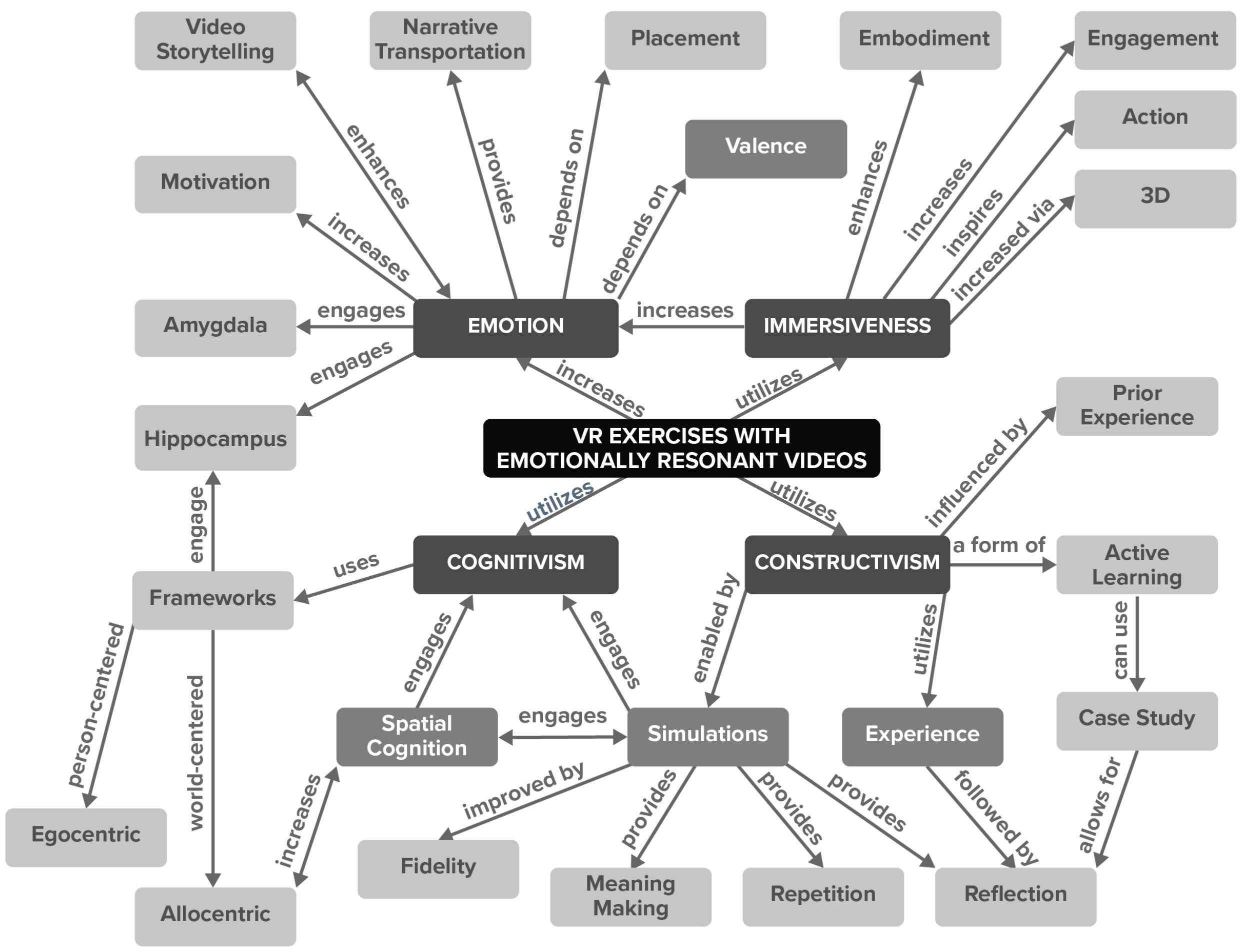
A primary contention of this study is that increased efficacy of safety training for contractors might yield a greater chance for transfer of learning; ensuring a greater likelihood that the safety lessons learned at the training site are utilized and applied at the jobsite. According to Haskell (2000), this transfer of learning is the learner's ability to apply what has been learned in training in another similar, yet wholly different, context. However, Haskell states, that most academics agree that transfer of learning rarely occurs. Haskell emphasizes that experience, and the learner's ability to build on previous experience is vital for all levels of transfer of learning. Haskell identifies six levels of transfer of learning including: (a) nonspecific transfer, where learning has a trivial connection to past experiences for the learner, (b) application transfer, where learning is applied to a specific situation, (c) context transfer, where learning is applied in a slightly different context from that in which it was trained, (d) near transfer, which is similar to context transfer but where learning is transferred to new or similar situations, (e) far transfer, where learning is applied to a new situation, and (f) creative transfer, where learning is applied in new ways and where new concepts could be created. This study was primarily concerned with focusing on application transfer, context transfer, and near transfer as these are the levels that most closely follow the challenges that contractors face in their line of work and training.

Haskell (2004) writes that "transfer is pervasive in everyday activities. New things often are understood in terms of past experiences, as being like something already familiar" (p. 576). The idea of new things being understood in terms of past experience is at the heart of constructivist adult learning theories where learning is built by constructing new concepts based on previous experience and reflection. To encourage a greater likelihood of transfer of learning occurring, this study employed the development of a variety of memory cues to help adult learners retrieve these memories at a later date, a key concept in Brown's (2014) work.

This study hoped to encourage the development of as many learning and memory cues as possible using the adult learning tools and techniques inherent in the study's design. This study design is shown Figure 2.1 which shows a graphical representation of the concepts used in this study presented as a concept map, a style of schematic illustration supported by Novak and

Gowin (1984). The authors write "Because meaningful learning proceeds most easily when new concepts or concept meanings are subsumed under broader, more inclusive concepts, concept maps should be hierarchical" (Nowak & Gowin, 1984, p. 15). For this reason, the primary concepts of: (a) cognitivism, (b) constructivism, (c) emotion, and (d) immersiveness are located near the center of the schematic and the subsidiary and tangential concepts radiate out from them.

Figure 2.1. Memory Retrieval Cues Used for this Study



The VR exercises used in this study were designed to help adult learners develop memory cues around simulations via active learning, allow the learner to experience a situation, remediate their mistakes, provide an opportunity to try exercises again, apply meaning to those simulations, and reflect on those experience when watching others go through a similar situation in the emotionally resonant videos. The emotionally resonant video was designed to help learners develop a network of memory cues by immersing the learner in a narrative story, feeling empathy for other workers in a similar situation to that which they experience, and using more memory development systems such as the amygdala and hippocampus. Being immersed in a VR simulation can also help adult learners develop more memory cues by allowing them to activate both allocentric and egocentric frameworks, and utilize space cells, grid cells, and other movement-oriented memory-making systems as a part of spatial cognition. Finally, a greater degree of fidelity and the reality of an immersive 3D environment should help adult learners develop more memory cues through being involved in a narrative story, and by the nature of the environment providing a sense of embodiment and activating more senses when exploring the environment.

Dewey theorized that learners construct new meanings from previous experiences and then follow those experiences up with reflection to gain understanding (Dewey, 1938; Merriam, 1993; Merriam & Bierema, 2014). As Dewey (1938) explains in *Experience and Education*, "Every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (p. 35). Kolb (1984) builds on Dewey's theories writing about learning as "the process whereby knowledge is created through the transformation of experience" (p. 38). Kolb writes when discussing Piaget's studies of human development that the learner's understanding and intelligence are guided by and developed by experience.

Experience and reflection are key facets outlined in Kolb's learning cycle where "action creates an experience, which is followed by reflection on both the action and the experience, which in turn triggers abstractions from the reflection, and ultimately new application of the abstraction" (Schott & Marshall, 2018, p. 844). This is the essence of Kolb's learning cycle in that the adult learner alternates between action and thoughtfulness, or active learning and reflection. This cycle is described by other learning theorists including Piaget (1977) who expresses that learning is a continuous cycle of mutual interaction between the accommodation of concepts to experience and the process of assimilating these experiences to previous world experiences. Kolb's learning cycle includes this interplay between action and reflection as it leads from concrete experience to observations and reflection followed by the formation of abstract concepts to the learner's testing of these concepts in new situations before starting the cycle again.

Multiple studies have shown how influential prior experience is on retention and memory-making (Bellana et al., 2021; Brod & Shing, 2022; Chen et al., 2018; Coleman et al., 2020; Dong et al., 2020; van Kesteren et al., 2018). Knowles (1970) writes about the greater volume of experiences that adults have, and how that depth of experience can help adult learners shape their learning. Writing on experience in general, Knowles et al. (2012) write that it is one of three primary categories that represent differences among individual learners. They discuss how adults can utilize crystallized intelligence, a combination of experience and education, and that this crystallized intelligence is more beneficial for future learning. These theorists all found that experience, and prior experience have an influence and effect on learning. More recently Dong et al. (2020) write about how prior experience can affect learning and memory capacity for learners. These findings suggest how prior knowledge had a positive effect both on learner engagement and retention as well as on resulting knowledge retention.

This study's framework provided learners the opportunity to interact with a simulated training environment and have that experience modified, allowing it to shape future experiences, and provide learners the chance to reflect and observe. The VR exercises provided as a part of this study allowed the learner to not just perform the actions that they were taught via the CBT course but when followed up with an emotionally resonant video, the learner was able to reflect, analyze, construct meaning, and build on concepts they had previous experience with.

Experience however is not the only aspect of this study that provided learners with greater opportunity for transfer of learning. Emotion also stimulates learning and more durable memories. Dirkx (2001) and Dirkx (2006) express the idea that emotion, whether or not the learner is conscious of emotion being applied in training, is a key tenet in constructivism and cognitivism. Regarding this use of emotion for deeper understanding, Dirkx (2001) states that when confronted with powerful emotions the learner will utilize mental images to construct meaning. Rühlemann (2022) echoes this by stating that emotion in terms of constructivism assists learners toward new understanding by pulling from experience and performing predictive modeling through allostasis, where allostasis is the brain's ability to anticipate, understand, and satisfy upcoming needs based on past experiences.

In terms of emotional moments creating deeper meaning leading toward cognitivism, Dirkx (2001) discusses how images charged with emotional resonance can provide learners the opportunity for a fuller understanding of the world and the learner's place in the world. Lazarus's (1991) writing on emotion and adaption expresses the deep link between cognitivism and emotion when he writes:

> Emotions are like no other psycho-sociobiological construct in that they express the intimate personal meaning of what is happening in our social lives and combine

> motivational, cognitive, adaptational, and physiological processes into a single complex state that involves several levels of analysis. (p. 6)

In their study of emotions' impact on memory, Tyng et al. (2017) write that stimulating learners' emotions can increase the chance for more emotional information to be encoded in the long term.

Brosch et al. (2013) find that emotion not only impacts the learner's degree of attention and perception during learning but also supplies an emotionally resonant moment for a learner, leading to more focused memory development. Brosch et al. specifically state:

> During the consolidation phase, memories are fragile and prone to disruption and modification. The memory trace representing an event can be strengthened (in this case, the memory will be remembered later) or weakened (in this case, the memory is forgotten or distorted). Emotion may modulate this consolidation process. (p. 4)

Simply, emotion can aid memory development and augment memory traces during encoding which in turn will make memories more durable. These views on emotion as a part of learning, both cognitive and constructivist-based learning, imply that emotion can be a fundamental and foundational part of training and can provide a greater opportunity for a more distinct transfer of learning.

This study engaged learners on multiple levels to inspire greater memory durability leveraging the power of narrative and the chance to tell a story that is relevant to the participants' personal lives, their work lives, and their job processes and procedures. This provides another opportunity to engage the adult learner in a critical meaning-making opportunity. As Zak (2014) finds in his studies on narrative and learning "character-driven stories with emotional content result in a better understanding of the key points a speaker wishes to make and enable better recall of these points weeks later" (para. 6). Providing an emotional story with a compelling narrative that the participant has acted out in a simulation, using technologies that are shown to enhance emotions, provided this study the opportunity to increase the chance for transfer of learning by ensuring greater memory durability for the learner.

Summary

This study used both constructivist learning theories and cognitivist learning theories to inspire greater memory durability in adult learners. This chapter provided information on how constructivist learning theories, cognitivist learning theories, emotion and storytelling as well as an immersive environment can play a part in creating multiple memory cues for greater memory retrieval and thus retention. Constructivist theories utilize experience, active learning, prior experience, and simulations. Cognitivist learning theories that this study hopes to leverage include using allocentric and egocentric frameworks, and spatial cognition to develop memory cue points. Applying an emotionally arousing, job-relevant video to the course design not only provides increased engagement through greater multimedia design but also promotes emotional responses which past studies have proven helps learners retain information longer than those experiences that are not imbued with emotion. Immersiveness provided via the VR tool has also been shown to not only heighten emotion and lead to greater emotional arousal, but also help to encourage willingness and interest in accomplishing tasks when the VR environments use narrative and storytelling. This chapter also reviewed the literature and studies that support the conceptual framework.

Chapter 3 - Methodology

This study followed an experimental research design using quantitative data analysis by manipulating an independent variable, the courses, and how information is presented to the participants. This research design is classified as a randomized multiple treatments design and a control group with a post-test-only design (Bridgmon & Martin, 2013; Creswell, 2013). Keppel (1991) writes that most quantitative experiments are composed of a comparison of similar experiments. Specifically, Keppel states:

> Most experiments involving a qualitative independent variable can be analyzed as a set of smaller, more focused experiments. The primary characteristic of these miniature experiments is that they focus on a meaningful contrast between two (and sometimes more) treatment conditions. (p. 8)

Leavy (2017) discussing the benefits of quantitative research designs writes about their deductive nature and that they search for a rationale or patterns using a process that aims to prove or disprove a theory through tests. This study's design provided the opportunity to compare three similar courses and analyze the results to determine the participants' retention of information over a period of time. The three courses that were used for this study included: (a) a CBT entitled CS, (b) the same CBT with just VR exercises entitled CS-VR, and (c) the CBT augmented with VR exercises and emotionally resonant videos entitled CS-VR-V as shown in Table 3.1.

Table 3.1. Courses and Course Titles Used in this Study

Course Title	Course Elements	Description
CS	CBT Course	A confined space course that covers procedures and policies around confined space awareness and confined space entry work.
CS-VR	CBT Course VR Exercises	The same confined space course as the CS course that is augmented with VR exercises.
CS-VR-V	CBT Course VR Exercises Emotionally Resonant Video	The same confined space course as the CS course that is augmented with VR exercises and emotionally resonant videos.

Research Question

This study aimed to determine the relationship between tools and techniques integrated into CBT courses and the study participants' knowledge retention. Since this study hoped to determine if there was a relationship between the delivery methods, a research question was necessary (Creswell, 2014; Harkiolakis, 2021; Leavy, 2017; Williams et al., 2022). This study investigated whether or not there was a relationship between greater learner knowledge retention of confined space safety awareness material when instruction was delivered through CBT without VR exercises and emotionally resonant videos compared to CBT with VR exercises and emotionally resonant videos or CBT with only VR exercises. Leavy expresses that research questions should be deductive and designed to determine if there is a relationship between the variables. This study's research question can be stated as:

- Do differences exist in knowledge retention for contractors from the following three groups: those who completed confined space courses with VR and emotionally resonant videos, those who took confined space courses with VR, and those who completed confined space courses without VR and without emotionally resonant videos?

Hypothesis

In order to answer this research question, this study used a null and alternative hypothesis. This study tested the following hypotheses based on the research question. The null hypothesis for this study was:

> Ho. There is no difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

The alternative hypothesis for this study was:

> Ha. There is a difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

Sample

The sample for this study was taken from a population that includes contractors who visited a safety council in the Gulf Coast region of the Southern United States. These contractors were registered for training by their contracting organizations. After their initial registration by their contracting organization, study participants were automatically re-registered within the safety council learning management system (LMS) by a random registration application that was developed by the safety council's IT department under the direction of the primary researcher.

An advantage of using this procedure is that it allows for a large, diverse, sample to study from a homogenous community which would create more generalizable results (Creswell, 2013; Williams et al., 2022). Learners at safety councils are all adult contractors who work in the energy industry. They are similar in that they are all contractors. Using this sample provided a diverse group of participants from a variety of different organizations that specialize in an array of different tasks all within a specific industry. To ensure a balanced mix of participants this study utilized a random assignment technique similar to what is described by Williams et al. and Creswell that allowed for generalizable results, and one where "each member of the population has a known and calculable chance of being selected" (Williams et al., 2022, p. 55).

Typically, learners at safety councils come from different contracting organizations that support different industrial processes and trades; therefore, the study participants had widely different experiences with the theories and procedures that were provided in these courses. Although the learner population for this experiment all had previous experience with confined space awareness concepts provided within all of the courses, the degree of that experience differed; from brief conceptual, or theoretical understanding, to deep experiential understanding. This varying degree of experience with the course content and understanding of the hazards discussed in the training could have potentially affected the test scores; however, the strong research design described above is modeled off of conditions that can both help to overcome confounding or extraneous variables and allow for more generalizable results (Creswell, 2013; Bridgmon & Martin, 2013; Keppel, 1991; Williams et al., 2022).

A typical safety council in the Gulf Coast region of the Southern United States could see an average of 200 learners a week for confined space training. As Leavy (2017) and Creswell (2013) write, quantitative studies favor large samples for experiments to help make results more generalizable. This experiment was conducted over a three-month time frame to ensure that a sample responding to the follow-up quiz meets the sample size requirements outlined in Creswell and will help overcome potential sampling error. The experiment was continued until there were a minimum of 30 returned quizzes for each of the three groups. This according to Fraenkel et al. (2012) and Creswell (2013) is the minimum number of participants needed for analyzing "a correlational study that relates variables" (p. 146) as this study was designed to do. Wilson Van Voorhis and Morgan (2007) writing on appropriate sample sizes, state that the minimum number of participants needed for a between-subjects study in order to maintain adequate power, " . . . given a medium to large effect size, 30 participants per cell should lead to about 80% power" (Wilson Van Voorhis & Morgan, 2007, p. 48). So this study was not bounded by a timeline, but rather continued to a minimum of 30 participants in each group were tested.

Research Design

This study used a quantitative research design to investigate knowledge retention. This design is similar to other research studies that have worked to determine if VR provides learning advantages over other forms of digital learning (Barsom et al., 2020; Harman et al., 2017; Kamińska et al., 2020; Mystakidis et al., 2022). Participants were randomly assigned to one of the three different courses by the safety council LMS at the time of their registration. According to Bridgmon and Martin (2013), the most effective way to control for extraneous or confounding variables is by ensuring that each participant has an equal chance of being a part of the control group or experimental groups. This is done by random assignment. The CS-VR course and CS-VR -V course both acted as experimental treatments. They both included VR exercises that gave participants a chance to practice procedures learned in the CBT course in an immersive virtual world using a VR headset. The CS-VR-V course included a video designed to elicit an emotional response for the learner, as well as provide participants an opportunity to reflect on the VR exercises and the procedures they learned. The CS course acted as a control group as it had neither a VR exercise nor an emotional video.

The proposed research design also offered the researcher the opportunity to provide three distinct courses to different groups of participants at a safety council, collect data from these groups, and directly compare participants' responses between conditions following a delay period. Researchers would classify this research design as a control with a post-test-only design or a test with randomized multiple treatments (Bridgmon & Martin, 2013; Burkholder et al., 2019; Creswell, 2013). The benefits of this design are that it includes three important aspects of experimental research including: (a) random assignment, (b) the opportunity to include a control group, and (c) the chance to manipulate an independent variable (Bridgmon & Martin).

The experimental design for this research is similar to a completely randomized design, or between-subjects design as outlined in Keppel (1991). As Budiu (2018) writes the strength of a between-subjects design over a repeated measures design or within-subjects design is that there is less chance of unintended learning occurring within groups or before the delay period is complete and changing the participants' understanding of the course and thus altering the collected data.

This experimental design is advantageous in that it provides the researcher the chance to analyze not only if VR exercises with emotionally resonant videos encourage greater knowledge retention, but also whether the emotionally resonant videos were effective compared to VR exercises alone. When the emotionally resonant videos are combined with the VR exercises, the combination of the two tools tells a story that is designed to further develop and increase the learner's understanding of the learning objectives and apply relevance and meaning to the learning. This means that the emotionally resonant videos would not be effective as a learning tool when used as a stand-alone learning device; therefore, there is no treatment that includes the CBT course augmented with video alone. This design allowed the researcher to determine if VR exercises augmented with emotionally resonant videos were effective for this sample population compared to non-VR treatments and VR-only treatments. Additionally, asking participants to provide answers to a follow-up quiz following a delay was designed to simulate the time that would elapse between a learner's completion of a course and departure from the safety council and their return to their work environment and is similar to prior studies that aimed to measure knowledge retention after the application of a treatment (Bréchet et al., 2019; Kamińska et al., 2020; Karpicke & Roediger, 2008; Krokos et al., 2019).

Protection of Human Subjects

Confidentiality was maintained for all research participants using processes developed from principles found in Bos (2020). Data was not linked to the participants' names or other identifying information. Once downloaded from the LMS, this information was kept on the primary researcher's computer, in a password-protected folder on a secured hard drive. The data was not stored on the safety council network. The researcher's computer was kept in a locked office. No one other than the primary researcher had access to that office without the researcher being present. The participants' names were not shared with their organizations, contractor organizations' names were not shared, nor was any of this information included in any articles or papers that are written as a part of this research. No hard copies of data collected from this study were produced. All of the digital records, drafts of work, or other information regarding the participants information within this study will be deleted after three years. This will be done with the assistance of the safety council IT team to ensure that the records are completely deleted.

Data collection did not begin until the study was approved by the executive leadership team of the safety council and approved by the Kansas State University (KSU) Institutional Review Board (IRB). No raw data collected from this study or any of the surveys was disclosed to the public nor to the contracting organizations that the study participants work for. Adherence to ethical protocols was an important consideration for the validity of this research study, therefore before the data collection phase, approval of the application to the KSU IRB was received. This step was taken to ensure participant confidentiality and ethical procedures were reviewed for the protection and storage of data collected for use in this study. Study participants' names were not used during the collection, only the demographic data and follow-up quiz scores were used during data analysis. This information was not linked to the participant's name or safety council ID number at any time after the initial collection.

The emotionally resonant video that was a part of the CS-VR-V course reviewed an accident within the industry of a job task that the study participants might have been familiar with. The video was designed to inspire an emotional response by focusing on the accident or injuries and showed publicly available interviews with friends and family members of the employees affected by the accident. A disclaimer notice with contact information for a national PTSD outreach and consulting service through the Substance Abuse and Mental Health Services Administration (SAMHSA) was provided to the study participants at the end of the CS-VR-V course for study participants to use if the emotional video triggered trauma for the learners.

There was no possibility for financial gain for either the safety council, the researcher, the contractor organizations that the participants belong to, or any of the participants of this study. The study participants who completed these courses were expected to show better results in recall, but whether taking the CS course, the CS-VR course, or the CS-VR-V course, the study participants were fulfilling the compliance and regulatory training demands necessary for safe work in the field as mandated by their contracting organization, the refinery site, and federal workplace safety standards.

The sample, created when the LMS application assigned learners into one of the three groups in the LMS, follows random assignment principles, and ensured that no one at the safety council, nor the contracting organizations, would have a personal or professional relationship with any potential study participants in a manner that might have influenced the study or the participants' work.

Study participants were given informed consent to be a part of this study by accepting a consent form, shown in Appendix A, at the beginning of the CBT course delivery regardless of which course they might have taken. This was delivered at the time of course initiation via the safety council LMS. The informed consent form stated the following: (a) the purpose and description of the study, (b) participant expectations and participation requirements of the study, (c) participant rights, risks, benefits, and confidentiality protection, and (d) the participant's option to leave the study at any time. This consent was developed following principles outlined by Leavy (2017) to ensure that participants understand the voluntary nature of their participation, the fact that all data will remain confidential, that participants' names will remain confidential, and other information and details about the participants' rights.

Participants were provided with details of the precautions implemented to protect their confidentiality during and after the study. Participants were neither asked for nor provided a means to give information that would identify them after training was complete.

Variables

Quantitative research, according to Harkiolakis (2021) and Williams et al. (2022) is fundamentally, research into cause-and-effect relationship experiments where the application of independent variables is tested against a control group to help expose patterns that can be analyzed. This experiment consisted of an independent variable and a dependent variable which can be affected by variables such as those dealing with the participant's personal demographic or experience variables. The independent variable in this study includes the delivery method for the CBT course. The varying methods of delivery include: (a) course delivery without VR and without emotionally resonant videos, (b) delivery with VR exercises, and (c) delivery with VR exercises and associated emotionally resonant videos. The dependent variables consisted of the participants' follow-up recall quiz scores that the study participants took three days following the completion of the course.

There were multiple variables which according to Harkiolakis (2021) might be either moderators or mediators. These he states should be controlled as much as possible to help understand how they affect or interfere with the outcomes. These variables' influence on the results was held in check by the sample population size and random assignment of the participants. This ability to provide probability or random assignment, according to Williams et al. (2022) is the "gold standard in social research, but is not always possible, yet always to be desired" (p. 55).

These variables, shown in Table 3.2, were collected during the course delivery using an integrated form, shown in Appendix B, as they might impact the results of the participant's tests and were analyzed after the completion of the experiment to determine if they had any influence on the overall results. These variables were selected as they might have had an influence on the follow-up quiz scores and affect the results indirectly or directly, cannot always be detected, and the researcher will have no control over them (Creswell, 2014; Harkiolakis, 2021). These variables are similar to variables collected by other studies of this type within similar industries such as those performed by Lee et al. (2023) and Yin et al. (2017).

These variables were selected as the participants in this study came from a wide variety of organizations and positions with varying degrees of experience and prior experience in technology, confined space procedures, and the industry. Prior experience has been shown to affect knowledge retention for new material (Bellana et al., 2021; Brod & Shing, 2022; van Kesteren, 2018), so data provided to address the variables listed in Table 3.2 all focus on whether or not the participants had previous experience either: (a) with the content, (b) with the industry, (c) as a leader in the industry, or (d) with the technology that delivers the course. Participants with a greater degree of familiarity with these characteristics in the study might have provided different answers or might have developed memories differently than those participants with less familiarity. All of these variables were captured using either multiple-choice questions or a 5-point Likert scale question which is "frequently used in social sciences to capture perspectives in ordering form" (Harkiolakis, 2021, p. 52). They were stored in the safety council's LMS for analysis after the collection of data was complete.

Each participant's age, gender, and race/ethnicity were collected when the course was administered. This information was collected via a survey that was integrated into the course. This data was stored in the safety council's LMS. These variables were selected to ensure that if there were effects observed with any of these variables, the magnitude of these effects could be analyzed.

Table 3.2. Variables to be Captured as a Part of this Study

Variable Type	Variable	Rationale	Collection Method
Independent Variables	VR exercises with video (CS-VR-V course)	To determine if VR exercises and videos contribute to more durable memory	NA
	VR exercises (VR course)	To determine to what degree VR exercises contribute to more durable memory	
Dependent Variable	Follow-up quiz Scores	To measure the extent of durable memory between treatment groups	Quiz score

Demographic Variables	Age	To determine if age has an interactive effect on the main effect of quiz scores	Dropdown pick list of ages
	Gender	To determine if gender has an interactive effect on the main effect of quiz scores	Dropdown pick list of gender types with "Other" and "Prefer not to answer" as selections
	Race/Ethnicity	To determine if race/ethnicity has an interactive effect on the main effect of quiz scores	Dropdown pick list of race and ethnicity selections
Industry/ Training Variables	Industry experience	To capture the years of experience the participant has worked in the industry around industry hazards like confined spaces	A dropdown pick list of numbers representing years in the industry
	Confined space experience	To capture the years of experience the participant has worked around hazards like confined spaces	A dropdown pick list of numbers representing years
	Proficiency with English	To determine the degree of English proficiency the learner feels they have	5-point Likert scale with selections from "I struggle with English" to "Native Speaker" selections
	Confined space leadership or supervisory experience and training	To capture whether or not the participant has had leadership or confined space supervisory experience or training	Yes or No selection
	Experience with confined space incidents	To determine if the participant has been involved in confined space accidents or incidents	Yes or No selection
Technology Variables	Familiarity with CBT	To determine if participants have used CBT often in their work and life	5-point Likert scale with selections from "No Experience" to "Very Experienced" selections
	Familiarity with VR training	To capture the years of experience the participant has with virtual reality tools and technology	5-point Likert scale with selections from "No Experience" to "Very Experienced" selections
	Familiarity with technology (ie. smartphone, YouTube, etc)	To determine if participants are familiar with different types of technology in training	5-point Likert scale with selections from "No Experience" to "Very Experienced" selections

Instrumentation and Course Design

Each group within this experiment included a CBT with the same course content delivered in a similar manner. However, the CS-VR-V and CS-VR courses, which both act as experimental treatments, included VR exercises that gave participants a chance to practice procedures learned in the CBT course in an immersive virtual world using a VR headset. All of the assets and courses described in this study had been developed previously but were reconfigured to support this study. The CS-VR-V course included the VR exercises as well as emotionally resonant videos that were shown within the VR headset immediately after the VR exercises were completed. The digital elements that made up the different groups and approximate time to complete are shown in Table 3.3.

Table 3.3. Digital Elements Used in this Study

Course	Digital Elements within the Course	Approx. Duration (min)
CS	CS – Digital CBT that reviews the theory of confined space work, policies, and procedures.	60
CS-VR	CS – Same as above CS; digital CBT that reviews the theory of confined space work, policies, and procedures. VR – Same as above VR; two, digital VR exercises that allow participants an opportunity to practice confined space simulations in a virtual scenario.	70
CS-VR-V	CS – Same as above CS, digital CBT that reviews the theory of confined space work, policies, and procedures. VR – Two, digital VR exercises that allow participants an opportunity to practice confined space simulations in a virtual scenario. V – A digital video that builds on the information in the VR exercises that analyzes an accident in a confined space designed to compel a sympathetic emotional response from the participants.	75

Computer-Based Training Course

The CBT sections of the courses were developed using Articulate Storyline course development software and included digital assets and adult learning techniques designed to help participants understand information and objectives as outlined in texts on multimedia learning by Lee et al. (2000), Mayer (2014), and Mellet-d'Huart (2009). The CBT included industry-standard information developed with the following:

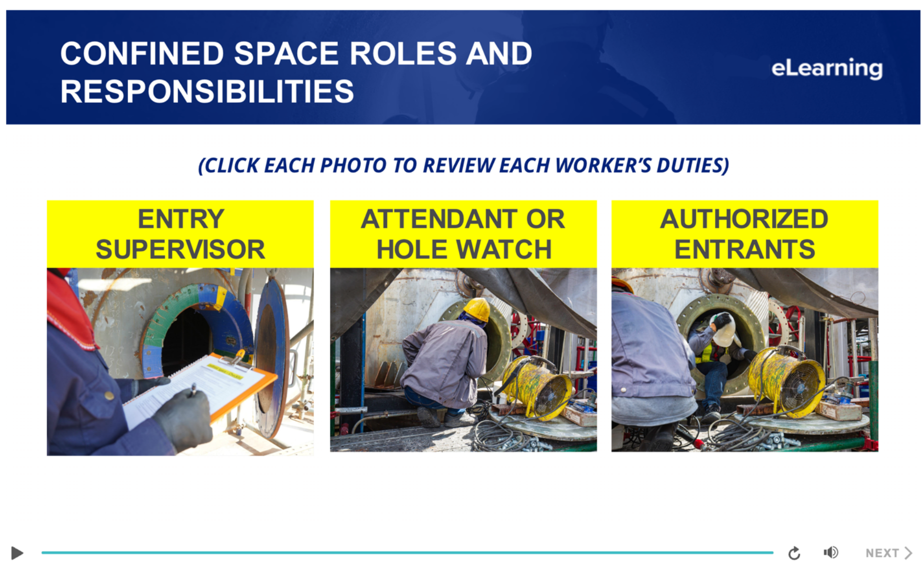
- audio narration
- an unscored pre-test
- animations
- explainer videos
- interactive scenarios
- 26-unscored, in-course knowledge check questions with remediation for incorrect answers
- a 25-question course final exam

The course was designed with eight modules including: (a) Welcome/Introduction, (b) Types of Confined Spaces, (c) Confined Space Roles and Responsibilities, (d) Confined Space Entry Permits, (e) Confined Space Hazards, (f) Emergency Response, (g) Conclusion, and (h) Final Test.

To aid learners and to compensate for any lack of English reading proficiency, English audio narration was provided on each slide of the course. Learners were also able to toggle a hyperlink on the navigation buttons to see a full transcript of the narration. On-screen text effects, bulleted lists, numbered lists, and paragraphs of information were also provided to help aid the learner in comprehension of the learning material. Job and procedure-relevant images were included on most slides as well as figures, drawings, and GIF animations to aid the learner in understanding the learning objectives.

Figure 3.1. Sample Slide from the CBT

Figure 3.2. Sample Interactive Slide from the CBT



Participants were able to navigate to each slide of the course only after completing the narration for each slide and being exposed to all information contained within that slide. Participants were able to move backward and repeat slides as many times as they might want, however, the entirety of each slide had to be completed before moving forward through the course. Each participant had to complete the entire course to take the final course exam.

Knowledge check questions that were similar to the questions on the final course exam were included at the end of each module to aid in the understanding of the course objectives and reinforce key concepts. Participants were given two chances to correctly answer each knowledge check question and were provided remediation after each failed attempt to help them understand the question and answer. Participants could, if they wanted, use navigation buttons to go back in the module to review knowledge check questions or answers, and information within the course before beginning the course exam.

Figure 3.3. Sample Knowledge Check Slide

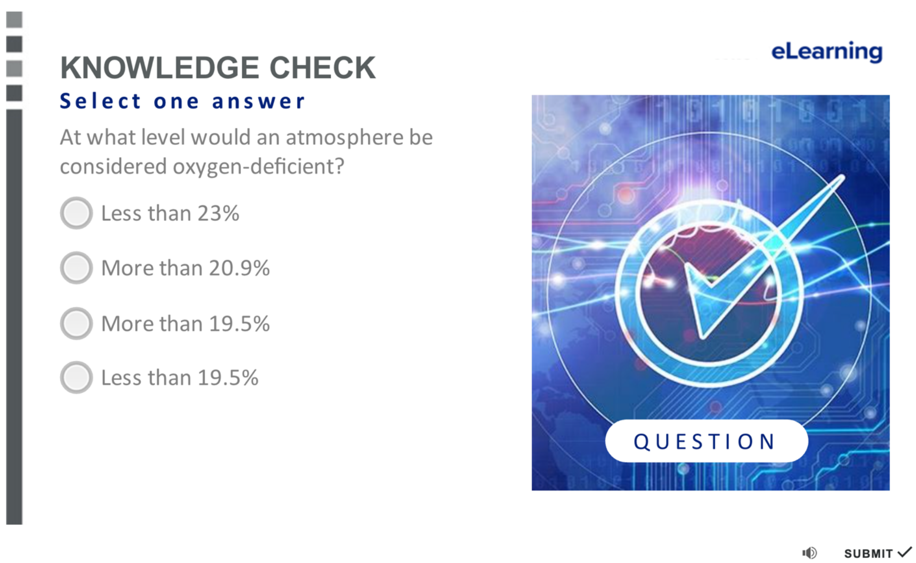
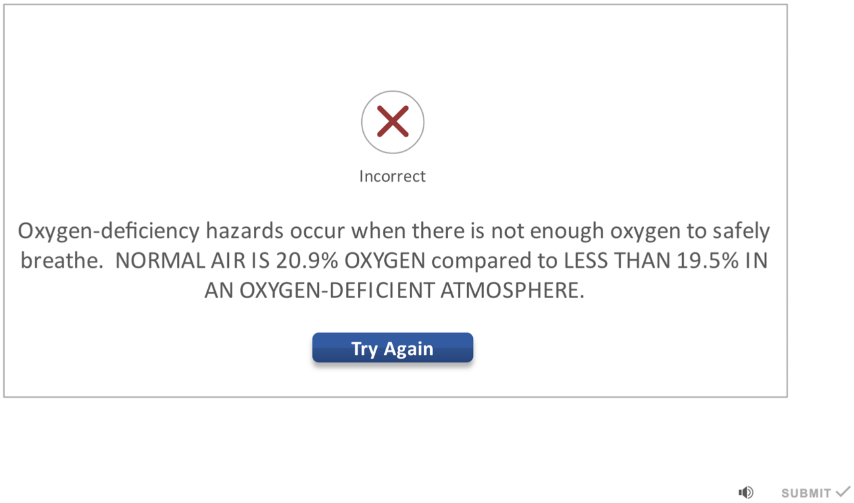


Figure 3.4. Sample Remediation Slide



The course exam questions, like the knowledge check questions, were a mixture of multiple-choice and true/false questions. Each question had only one correct answer. Participants were graded on the course exam and had to achieve a score of 80% to successfully pass and complete the course. Once participants started the course exam they had to complete the exam in its entirety. There were no questions on the course exam that referenced information that was only provided via the VR exercises or the emotionally resonant videos. Participants had one chance per question to get the questions correct. Remediation after wrong answers was provided. Each participant was provided a score on their exam immediately after completing the course. This course score was shown in terms of a percent correct.

Figure 3.5. Sample Final Exam Slide

Virtual Reality Exercises

The VR exercises were designed by the safety council's instructional designers with the intent to support the CBT course. There were four distinct exercises that participants had to complete in the VR groups including the introduction to VR exercise. Participants in this group took the VR courses at the same workstation as the CBT course without having to change positions. The VR exercises were developed using principles outlined in multiple research articles and studies such as those by Jerald (2015), Bertram et al. (2015), and Parong and Mayer (2018). The VR exercises were developed using the following software and applications:

- Visual Studio
- Unity
- Blender

The VR exercises were integrated into the CBT described above and provided to participants who took CS-VR and CS-VR-V courses. This course included:

- audio narration,

- four, timed exercises that support the information provided in the CBT, and
- a virtual space designed to simulate a jobsite that a contractor supporting the energy industry might encounter.

A tethered headset modality was used for the VR headset setup to simplify the launching of the VR exercises from the existing safety council PC-based courseware. Testing the tethered headsets showed that Oculus Rift S headsets provided the best performance. Seated modality, as opposed to room-scale, was used to best fit established safety council procedures.

The VR exercises were designed to last between three and five minutes each and were developed to help reinforce confined space knowledge and general practices or procedures. These exercises included: (a) an introduction to VR that helped participants understand how to use the VR equipment and interact with the virtual world, (b) an exercise on identifying different types of confined spaces, (c) an exercise that allowed learners to select appropriate personal protective equipment (PPE) and safety equipment to use for specific confined space types, and (d) an exercise that placed the participant in the role of a hole watch or safety attendant.

Figure 3.6. Sample Screen from the VR Exercise on Identifying Types of Confined Spaces

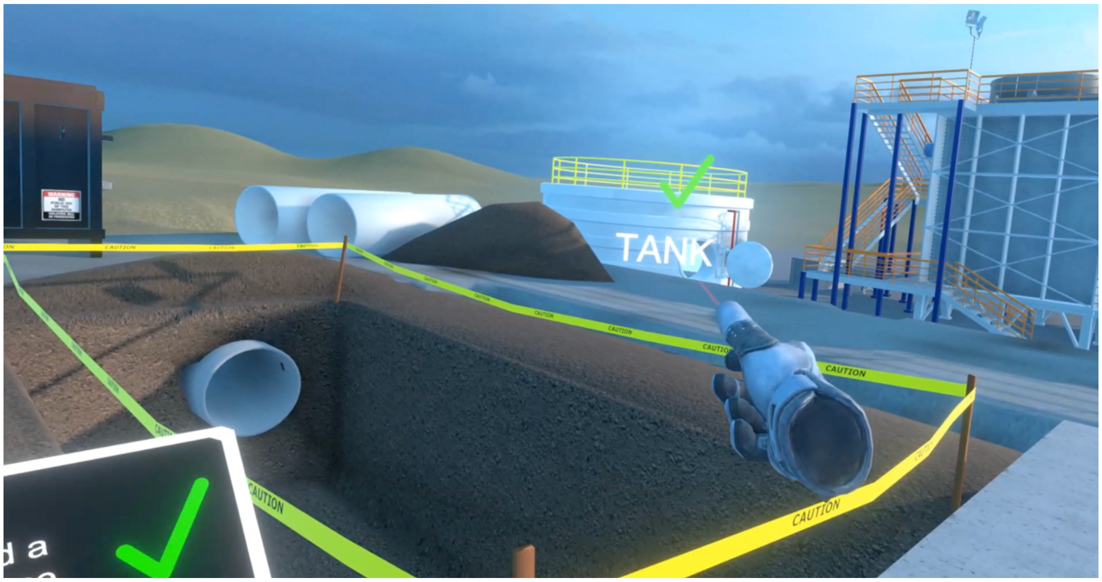


Figure 3.7. Sample Screen from the VR Exercise on Selecting PPE and Safety Equipment

Figure 3.8. Sample Screen from the VR Exercise of Performing Safety Attendant Duties

Although the exercises had timed activities, the participants were not scored on their ability to complete the exercises within the time frame. If the participant failed to complete all of the criteria in the exercise or complete the exercise correctly, a narrated remediation was provided and the learner was able to try again. All exercises had to be completed correctly for the participant to move on from the VR course.

Virtual Reality Exercises with Emotionally Resonant Videos

Participants assigned to the CS-VR-V group took the Articulate e-learning course described above and the VR exercises, as well as were provided a video that described a fatal accident that occurred in a manner similar to the procedure the participant enacted in the VR exercise where they were a hole watch or safety attendant. The emotionally resonant videos were developed using concepts from researchers focused on video storytelling such as Mar et al. (2021) and Zak (2015) as well as multimedia in training principles by Lee et al (2000) and Mayer (2020). These videos were integrated into the CBT course with VR exercises as described above and were provided to participants who took CS-VR-V. These videos included:

- a four-minute video story that reviewed an accident that occurred in an industrial setting that is similar to what contractors might see on a typical jobsite,
- publicly available news video clips of the victim's friends and family members' reactions to the accident, and
- a discussion by a trainer of the importance of the training.

Following concepts of temporal contiguity and essential processing, the emotionally resonant videos and VR exercises were oriented in the course so that they occurred near the theoretical information that they supported (Carmichael et al., 2018; Mayer, 2014). The emotionally resonant videos were produced by the researcher and the safety council to support the information in the VR exercises and were viewed immediately following the VR exercises using the VR headset, eliminating the need for the participant to remove the VR headset.

The video was developed and produced by the safety council using safety council resources. The video included an introduction by a safety council trainer discussing the hazards and challenges associated with confined space work. The video utilized newsreel footage and publicly available video footage to describe the incident for the participant. The video footage utilized for this video was deliberately selected to inspire a sense of empathy for the learner by including publicly available video testimonials about the victim from friends, relatives, and officials involved in the accident or who knew the victim.

Figure 3.9. Sample from the Emotionally Resonant Video

Figure 3.10. Sample from the Emotionally Resonant Video of Interviews

Participants had to watch the entire video in order to advance in the course. The video was shown within the VR headset immediately after the VR exercise that it supported. The participant did not have to remove or replace the headset, nor were they required to move from their workstation to view the video. At the end of the video, the participants were asked to remove the VR headset and continue the e-learning course. The video started automatically and could not be reviewed or watched a second time by the participant unless they chose to review sections of the CBT course and perform the VR exercises again. The proctors for CS-VR and CS-VR-V were asked to log instances where participants took VR courses or viewed the video twice.

Recall Quiz

All participants, regardless of group, were sent a follow-up quiz three days following the course completion. This follow-up quiz was developed using a fixed forced format following principles found in Leavy (2017). Scores from the follow-up quiz were collected and stored in the safety council LMS. This data was analyzed once the experiment was complete as described in later sections of this chapter. This three-day delay is in line with other studies that measure VR course efficacy and knowledge retention (Bréchet et al., 2019; Kamińska et al., 2020; Karpicke & Roediger, 2008; Krokos et al., 2019).

The follow-up quiz consisted of five multiple-choice questions designed to judge the study participant's knowledge retention of the learning objectives regardless of treatment. The score on the quiz ranged between 0–100. These questions were multiple-choice questions with only one correct answer and three incorrect answers per question. Past internal studies performed by safety councils have found that a high respondent burden, which Leavy (2017) defines as asking learners to perform tasks that are too drawn-out or cumbersome, has led to fewer results from participants. High burden, Leavy continues, leads to respondent fatigue which yields a low response rate. For this reason, this study limited the number of questions to increase response rates from the study sample. Additionally, the questions were limited to multiple choice and true/false questions as past studies have found few learners provide answers to open-ended questions. As Bailey et al. (2015) write about interactive digital interventions (IDI), a primary challenge for quizzes delivered via SMS as this study proposed is ensuring that the follow-up quiz is completed. Safety council proctors encouraged all learners to complete the online interventions and asked them to look for and complete the follow-up quiz on their phones after the three-day delay.

This follow-up quiz was delivered via SMS technology and arrived three days following course completion. A reminder text was sent to the learner's smartphones via SMS the day after course completion to establish contact with the learner and help influence learners to complete the follow-up quiz. A follow-up reminder was sent within ten days following course completion to those learners who were non-responsive after the initial three days.

The software that was used to deliver the follow-up quiz to the study participants was developed and administered by the safety council's IT department under the direction of the primary researcher and leveraged the same software as the safety council's LMS, registration system, and course delivery system. These course registration and delivery assets were developed by the safety council and the researcher had access to all test and course information by accessing the LMS. The LMS is able to pair registration information, variable and demographic information, and follow-up quiz scores so that the information could be analyzed.

Instructional Design

All of the instruments used for the study were developed by: (a) the primary researcher, (b) the safety council's e-learning development team, and (c) the safety council's IT department. All of these instruments were designed and developed under the primary researcher's direction. This safety council's e-learning development team has over 100 years of collective experience working with subject matter relevant to the content of this course and is familiar with the course objectives and OSHA standards. All of the content was reviewed by industry subject matter experts (SME) and by certified safety professionals (CSP) for content correctness and adherence to OSHA standards in accordance with established safety council course development procedures.

All of the elements within this study were developed in a digital format to guard against the influence of tautology, or the opportunity of saying the same thing in different ways, which might arise if a non-digital, instructor-led course was provided to the groups. Bailey (2015) expresses that digital interventions ensure a strong research design in that each participant is provided the same foundational information by taking the CS course. This consistency, as well as the consistency inherent within the digital format of the CS course, the CS-VR course, and the CS-VR-V course ensured that the participants within all of the groups were provided the same information in a similar manner.

Data Collection

Data collection procedures followed established safety council learner identification and test-taking policies similar to those found at the Higher Learning Commission (HLC) (2022). Creswell (2013) writes of the importance of standardization in data collection by writing about procedures and instrumentation, "in all of these cases, it is important to use standard procedures. When procedures vary, you introduce bias into the study and the data for individuals may not be comparable for analysis" (p. 169). This study used established data collection procedures described in this section and in use by the safety council.

Study participants, regardless of condition took their courses at a safety council contractor training facility using one of the standard computer terminals used by that council for course delivery. Registrations by the contractors for the courses were done in the safety council LMS using the safety council's established procedures. Collecting participants' cell phone numbers within the safety council LMS at the time of registration is a part of that procedure. All of the safety council's computer terminals that were used for this study were similar and were proctored by safety council proctors at all times during the delivery of any courses. All participants, regardless of condition, were proctored by safety council proctors and were allowed the opportunity to ask questions regarding the delivery of the courses.

Study participants who took the CS-VR-V course or the CS-VR course were proctored and assisted in the use of the VR equipment by safety council proctors who were trained for this purpose. The safety council installed eight computer terminals with Oculus Rift S VR headsets that were configured to provide CBT courses, VR exercises, and emotionally resonant videos. These courses were developed to be delivered via the safety council's proprietary course delivery player through the safety council LMS. The safety council proctors were trained to provide oversight, enforce lab rules, and aid learners in the use of the course delivery terminals and the use of VR equipment, without providing aid to the learner that might have changed how they answered questions within the course, within the VR exercise, or after the course was complete.

The safety council proctors also ensured that learners did not cheat, benefit from other learners' information, or make use of aids during the course. The safety council proctors undergo rigorous onboarding training and mentoring. This training includes an initial proctor training CBT, an annual refresher CBT, as well as mentorship by other proctors and supervisors within the safety council computer training labs. The primary researcher, the safety council training and operations managers, and the safety council's supervisors were all available to help proctors with any issues that arose during course delivery within the experiment's time frame.

All safety council CBT lab training stations are isolated from neighboring training stations by partitions. Training integrity was monitored by an established and audited safety council learner verification process which verified learner identification against a valid picture ID and other biometric data located in the safety council LMS. Participants for this study followed an established process that safety council learners follow. The safety council learner verification process includes three standard, progressive, identification checks, and spot checks throughout the learner's completion of any CBT. This process is audited annually by a third-party organization to ensure adherence to the following policies and procedures.

The three times the learner's identification was verified throughout the process of completing these courses or any of the safety council course(s) include: (a) at the registration desk when the learner entered the safety council lobby and received a training ticket, (b) when the learner arrived at their workstation, and (c) when the learner completed their course(s). Additionally, proctors spot-checked throughout the course delivery process to ensure that the learner who checked in and started the course was the same learner who took the course.

The study participant's picture was displayed for the safety council proctor to use as a point of comparison at every training station that the participant used at all times during the course delivery, regardless of group. This picture were taken as a part of the safety council's learner verification process, at the time of the learner's initial registration and is updated by safety council proctors after initial registration. This picture was saved in the safety council's LMS and is updated annually or when there were significant changes to a learner's facial features such as the learner growing a beard or mustache.

The participants were asked to provide demographic and other industrial variable information as described in Table 3.2, and shown in Appendix B. This data collection form was integrated into the course, at the beginning of the course, and took less than two minutes for any participant to complete. All fields used multiple-choice questions. The participants had access to a keyboard and mouse to input their information. The safety council proctors were trained on how to help any participants who might have had questions regarding this form.

The VR exercises that were part of the CS-VR course and the CS-VR-V course were administered at the same workstation where study participants completed the CBT sections of the courses. Study participants in the two experimental VR treatments completed the VR exercises using an Oculus Rift S VR headset provided by the safety council. Study participants who were assigned to complete CS-VR-V treatment viewed the videos once they completed the second VR exercise with the Oculus Rift S VR headset.

Study participants who did not wish to participate in the VR exercises that were a part of the CS-VR course or the CS-VR-V course were allowed to take the CS course and the study participant's course data from the follow-up quiz were removed from the sample population and not a part of the experiment's analysis. Study participants who did not wish to participate in completing the follow-up quiz left the follow-up quiz unanswered and their data was not a part of the analysis. Study participants who failed courses or had an opportunity to take the course, the course exam, or the recall quiz twice were removed from the data before analysis. This was done to ensure that those participants who had multiple opportunities to learn the material in the course did not take the recall quiz and affect the internal validity of the study from the learning effect or practice effects (Harkiolakis, 2021). This study followed a between-subjects design. Allowing participants to take course exams or recall quizzes multiple times would change the design to include a within-subjects design. This would allow for repeated measures from participants taking the course more than once (Seltman, 2018).

Study participants who opted out of being a part of the study were advised by a safety council proctor to not complete the consent form. This ensured that no follow-up quiz was sent to that participant's phone and that the participant's data would not be collected as a part of this study. This was noted in the participant's safety council LMS record, and the participant's data was not used as a part of the study.

Any participant who was concerned about motion sickness or who experienced motion sickness as a part of the CS-VR course or the CS-VR-V course was offered the chance to take the CS course. These participants and any data that was received from their follow-up quiz were removed from the data set and not analyzed. Every consideration was taken to ensure motion sickness was mitigated in the VR exercises. In their study on VR headsets and motion sickness, Chang et al. (2020) find:

> [There is] not a single but multiple factors of a VR system are related to users' discomfort. Though there has been an effort to reveal a few prominent factors for determining VR sickness, this review showed a multi-faceted characteristic of VR sickness. Therefore, it is required to consider the various components of the virtual environment simultaneously to design a user friendly VR scenario. (p. 1678)

For this reason, the safety council VR simulations included short exercises, with a seated modality where the field of view was limited. Additionally, the learner performed all of the activities in the exercises from one position, rather than multiple areas.

Jerald (2015) discusses the cause of motion sickness in VR simulations as primarily due to the conflict for the learner between their visual and vestibular senses, where vestibular senses are those that maintain balance and provide information about body position. Jerald describes this as sensory conflict theory. Although the lack of excess movement in the simulation, the short timeframe of the exercises, and the seated modality are designed to minimize or negate this conflict between the visual and vestibular senses, this study took the following actions for learners who experienced motion sickness. Study participants who were concerned about motion sickness, or study participants who reported motion sickness during the VR exercises were provided the opportunity to take the CS course that did not include VR exercises and their data was excluded from the analysis. The safety council has provided courses with VR exercises that are similar to what is found in both the CS-VR course and the CS-VR-V course for over two years and has not had a single reported instance of a learner experiencing motion sickness.

Quizzes were provided on the learners' smartphones using an established SMS technology that the safety council has used in previous studies. Reminders that asked the participants to complete the quiz were sent to the study participants, but only to those participants who had not been sent a previous reminder. This ensured that participants were sent only three texts; (a) an introductory text to encourage the learner to use the link, (b) the recall quiz questions, and (c) a reminder text asking them to take the recall text. Data obtained from the follow-up quizzes was stored in the safety council LMS. Only the primary researcher had complete access to the information on participants' follow-up quiz scores, consent forms, personal information, or answers to demographic variables and other variables that were collected.

Data Analysis

Once data was collected from the study participants, various measures were used to address and provide insight to answer the research questions based on principles of analysis provided by Keppel (1991), Bridgmon and Martin (2013), and Williams et al. (2022). Data from the variable collection form and the follow-up quiz scores were imported into SPSS software to analyze and address the research questions.

One-Way Analysis of Variance (ANOVA)

This study is based on an experiment that is designed to test the difference in mean scores between more than one group. An ANOVA analysis is appropriate to use for the analysis of multiple means as Levine and Stephan (2014) write that "unlike the t-test, which compares the difference in two means, the analysis of variance simultaneously compares the differences among the means of two or more groups" (p. 183). A test of between-subject effects helped to make a decision to reject the null hypothesis more certain as there was natural variability between treatments. Schuster (2021) states:

> This is the 'good' kind of variability, the variability due to the treatment effect. With more between-group variability, we are more certain that the groups are different, and we are more likely to reject the null hypothesis. Between-group variability also includes variability (differences) due to random chance. (p. 1)

Levene's Test of Equality of Error

As stated by Gastwirth et al. (2009), "Before comparing the sample means, one should check that the underlying populations have a common variance" (p. 3). Completing Levene's test of equality of error helps to ensure that the data included equality of variance across all means in the sample treatments, a necessary assumption for an ANOVA, which ensures against falsely rejecting the null hypothesis (Salkind, 2010).

Effect Size Estimates

According to Bridgmon and Martin (2013), a test of between-subject effects helps to make a decision to reject the null hypothesis based on the partial eta squared value. The partial eta squared value for the data will provide information on the practical significance and can help make a determination on the effect of the results on the sample and the generalizability of the results (Wilson Van Voorhis & Morgan, 2007). Wilson Van Voorhis & Morgan report regarding effect size that "Cohen conventions suggest an effect size of .20 is small, .50 is medium, and .80 is large" (p. 48). Sullivan and Feinn (2012) argue that effect size is as important if not more important than statistical significance alone.

Bonferroni Correction

When discussing which post-hoc test to interpret and analyze the results of an ANOVA, Zach (2020) writes, "The Bonferroni post-hoc test should be used when you have a set of planned comparisons you would like to make beforehand" (para. 18). When there are "planned comparisons we'd like to make ahead of time like this, the Bonferroni post-hoc test produces the most narrow confidence intervals, which means it has the greatest ability to detect a true difference between the groups of interest" (para. 20). A Bonferroni test was proposed as this study intended to compare results between two sets of conditions as follows:
(a) CS and CS-VR-V, (b) CS-VR-V and CS-VR, and CS and CS-VR if a statistically significant relationship is found. If the results of the study show a non-statistically significant result in the scores among the groups, a Bonferroni Correction will not be necessary as this test helps to ensure against making a Type 1 error when rejecting the null hypothesis. When there is no statistical significance we fail to reject the null hypothesis (Keppel, 1991) and there is no chance to make a Type 1 error.

Descriptive Analysis

The analysis of the main effects also included the following descriptive statistics:
(a) mean scores on the follow-up quiz, (b) the standard deviation of the data, and (c) ranges of the follow-up quiz scores. Focusing on these factors and using the analysis from the above tests and post-hoc tests helped the researcher reject or fail to reject the null hypothesis.

Summary

This chapter describes the research design, a randomized multiple treatments design and a control group with a post-test-only design and methodology that were implemented for this VR and emotionally resonant video study. An overview of the methodology was provided describing the technology used in this research as well as the setting of the study, participants, data collection tools, data collection process, and data analysis. The limitations of the study, a list of the variables that will be collected and why, as well as information regarding ethical considerations concerning this study and how they were addressed and was also included in this chapter.

Chapter 4 - Findings

This chapter presents the results of a study that examined the effects of VR exercises with emotionally resonant videos and VR exercises without emotionally resonant videos on a sample of contractor learners at a safety council in the Gulf Coast region of the Southern United States between June 19, 2023 and September 23, 2023.

Study participants included any contractors who visited the safety council training site and were registered to take the safety council's confined space awareness course, an annual requirement for energy industry contractors in the area. The control group received traditional, non-VR instruction via CBT course delivery. The two experimental groups received the same CBT course augmented with VR exercises and emotional videos or VR exercises without emotionally resonant videos. All groups received a recall quiz that consisted of the same five questions in the same order designed to help measure knowledge retention of the course material.

Data from the recall quiz was analyzed to determine the effect of these different delivery elements on the participants' knowledge and recall about confined space procedures, dangers, and processes. This analysis focuses on the descriptive summary of the data and a one-way ANOVA to determine if there is a statistical significance between the groups. An analysis of the demographic information was also used to further develop an understanding of the effects of the participants' different demographic or experience characteristics in regard to their recall quiz results.

Description of the Sample

The population for this study included contractors who work in the energy industry and who visited the safety council for confined space awareness training. Study participants came from various economic and academic backgrounds within the United States and primarily worked in specialized areas of the downstream energy and petrochemical manufacturing industries. All training was delivered and conducted in one of two e-learning labs at the safety council training site. These labs include dozens of computer workstations with equipment and personnel designed to ensure the integrity of the course delivery and to help assist participants as needed in the delivery of the courses.

During the study time period, the safety council had 42,372 visitors for training across all sites and online. Of those, 1,131 were registered for and assigned to one of the three groups for this study. Of these 1,131 potential participants, 634, or 56% completed the course and consented to be a part of the study. These 634 participants received a quiz delivered to their phones three days following the completion of their course. Of the 634 participants who received recall quizzes, 181, or 29% completed the recall quiz such that: (a) 50 of these responding participants, or 27%, had been randomly assigned to the CS group, (b) 60, or 33% of the participants who responded, had been randomly assigned to the CS-VR group, and (c) 71, or 39%, had been randomly assigned to the CS-VR-V group.

Because 634 participants took the courses and consented to be a part of the study, and 181 participants completed the recall quiz, more than 30 per group, the threshold for an appropriate sample size was met by this study. Descriptive statistics for each group of the recall quiz participants' scores are show in Table 4.1

Table 4.1. Recall Quiz Descriptive Statistics

Group	*n*	*Mo*	*Mdn*	*M*	*R*	*Min/Max*	*IQR*
CS	50	60, 80 (16)	80	70.40	80	20/100	60 - 80
CS-VR	60	80 (25)	80	76.67	80	20/100	60 - 90
CS-VR-V	71	80 (24)	80	76.90	80	20/100	60 - 100

Note. The maximum score is 100, Mo = mode, Mdn = median, R = range, IQR = interquartile range.

Additionally, based on the histograms of the recall quiz scores shown in Figure 4.1, Figure 4.2, and Figure 4.3, there was an approximately normal distribution of recall quiz scores across all three groups. This distribution of results and the descriptive statistics indicates that the results might be generalizable across a larger population (Bridgmon & Martin, 2012; Williams et al., 2022).

Figure 4.1. Distribution of Scores in CS Group

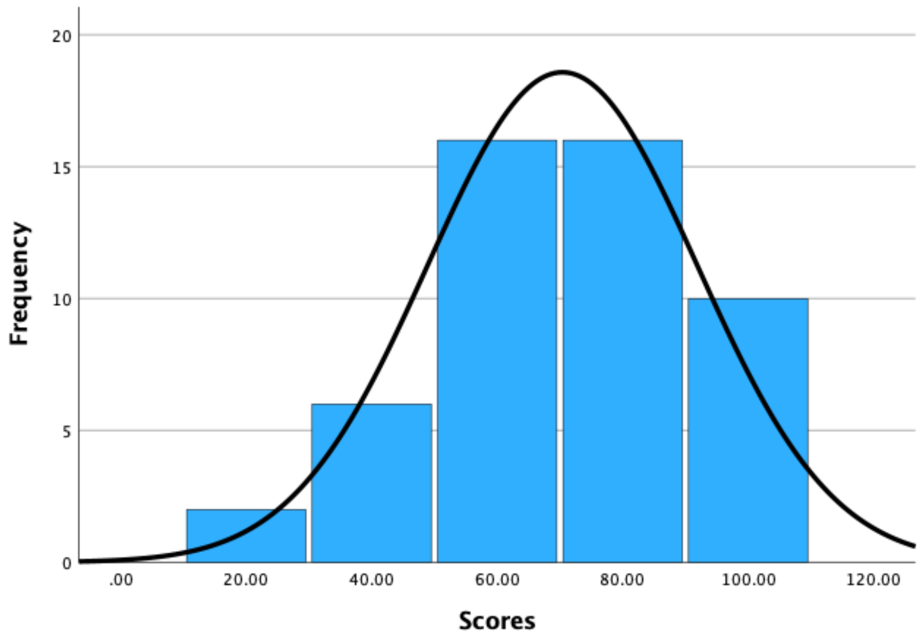


Figure 4.2. Distribution of Scores in CS-VR Group

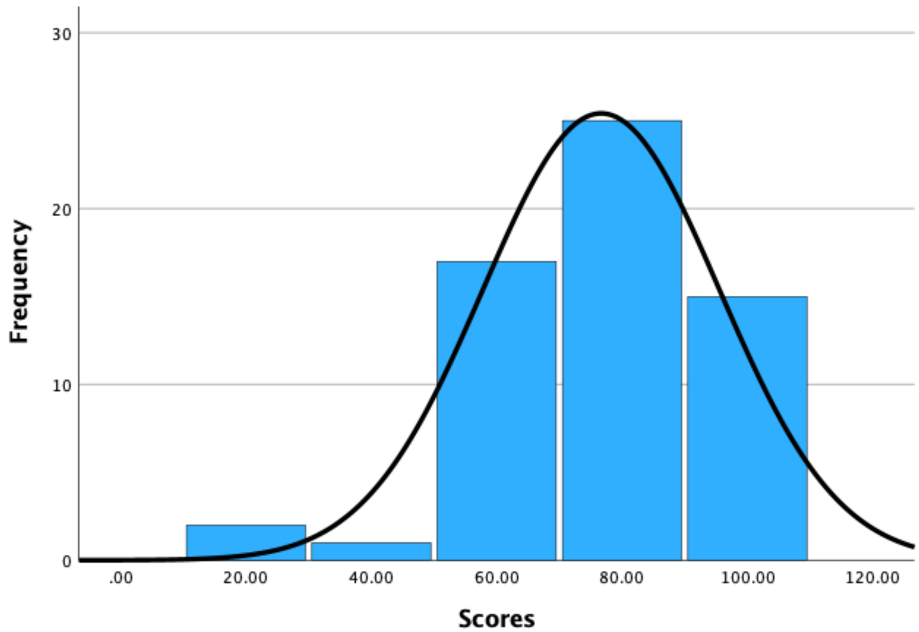
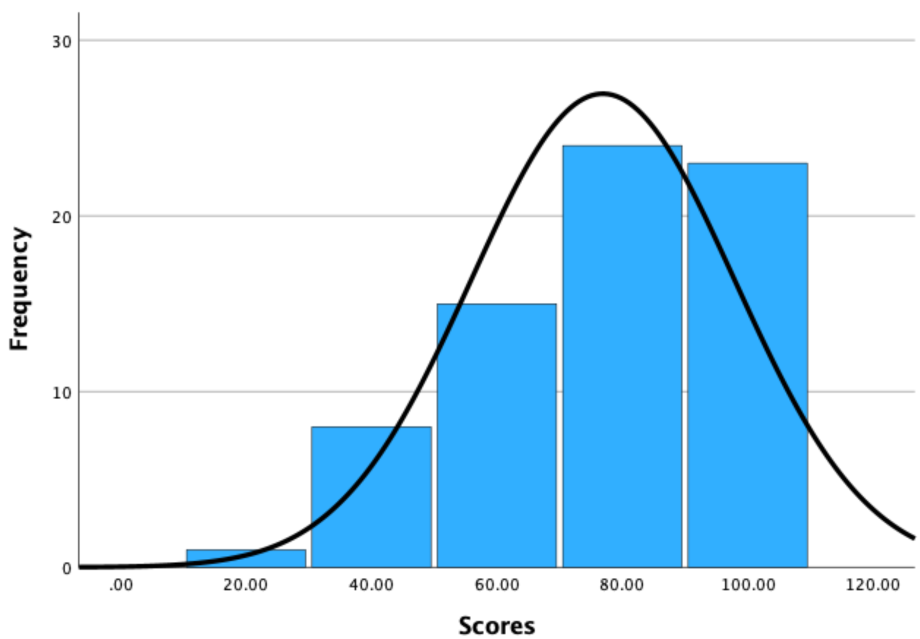


Figure 4.3. Distribution of Scores in CS-VR-V Group



Demographic Variables

Demographic information for the 181 recall quiz participants was collected and analyzed to ensure that different demographic and personal aspects of the participants in the sample did not potentially affect the outcome and results of the study. A form to collect variables about the participants was integrated into each course, near the beginning of the course. This information provided in Table 4.2, shows an overview of the demographic characteristics of the sample. Table 4.3, focuses on the experience level of the participants within the sample.

In terms of age, gender, and race there was an approximately normal distribution of participants across all three groups with no one group getting a disproportionately larger or smaller share of participants from another group. In terms of English proficiency, the participants indicated for all groups that they were proficient in English and this was similar across all groups, with no participants indicating that they were not proficient or not at all proficient in English. From this, we can deduce that there were no participants who could not understand the instruction, the test questions, the recall questions, or other aspects of the course that were presented in English. In terms of participants who completed the recall quiz who indicated they were Confined Space Supervisors or who might have held that position in their careers, there was an approximately equal number of leaders and non-leaders within our sample. Finally, as expected based on previous studies of this type at safety councils (HASC, 2020) and within this population, there were more male participants than female, with 94% of the recall quiz respondents being male.

Table 4.2. Demographic Characteristics

Characteristics	CS		CS-VR		CS-N-VR		Full Sample	
	n	%	*n*	%	*n*	%	*n*	%
Age								
18-24	5	3	20	11	21	12	46	25.4
25-34	11	6	16	9	19	10	46	25.4
35-44	17	9	16	9	19	10	52	28.7
45-54	14	8	5	3	7	4	26	14.4
54-65	2	1	2	1	5	3	9	5.0
65+	1	1	1	1	0	0	2	1.1
Gender								
Male	48	27	55	30	67	37	170	93.9
Female	2	1	5	3	3	2	10	5.5
Other	0	0	0	0	1	1	1	0.6
Race								
American Indian	0	0	2	1	0	0	2	1.1
Asian	1	1	1	1	1	1	3	1.7
Black/AA	12	7	8	4	6	3	26	14.4
Hispanic	24	13	36	20	42	23	102	56.4
White	8	4	13	7	18	10	39	21.5
Other	5	3	0	0	4	2	9	5.0
Confined Space Supervisor								
Yes	27	15	19	10	30	17	76	42.0
No	23	13	41	23	41	23	105	58.0
English Proficient								
Very Proficient	34	19	47	26	58	32	139	76.8
Proficient	15	8	12	7	13	7	40	22.1
Neither	1	1	1	1	0	0	2	1.1
Not Proficient	0	0	0	0	0	0	0	0.0
Not at all Proficient	0	0	0	0	0	0	0	0.0

This study also captured variables focused on prior experience as these might affect the recall quiz results. These variables focused on prior experience in terms of technology in training and working in confined spaces in the industry. In terms of industry experience, confined space experience, and experience with technology there was an approximately normal distribution of participants across all three groups with no one group getting a disproportionately larger or smaller share of participants with a higher degree of experience from another group. In terms of participants who had direct experience with confined space accidents or incidents and in terms of experience using VR technology previously, a large majority of the participants indicated they had never been in a confined space accident or incident nor had ever used VR technology before.

Table 4.3. Experience Characteristics

Experience Characteristics	CS		CS-VR		CS-N-VR		Full Sample	
	n	%	*n*	%	*n*	%	*n*	%
Industry Experience								
1-5	18	10	33	18	34	19	85	47.0
6-10	9	5	10	6	10	6	29	16.0
11-15	10	6	6	3	10	6	26	14.4
16-20	8	4	6	3	8	4	22	12.2
25+	5	3	5	3	9	3	19	10.5
Confined Space Experience								
1-5	22	12	36	20	35	19	93	51.4
6-10	10	6	10	6	9	5	29	16.0
11-15	11	6	3	2	10	6	24	13.3
16-20	4	2	7	4	11	6	22	12.2
25+	3	2	4	2	6	3	13	7.2
Confined Space Accident								
Yes	4	2	2	1	4	2	10	5.5
No	46	25	58	32	67	37	171	94.5
Experience with CBTs								
0-5	16	9	23	13	22	12	61	33.7
6-10	6	3	11	6	9	5	26	14.4
11-20	4	2	3	2	7	4	14	7.7
21+	24	13	23	13	23	13	80	44.2
Experience with VR								
0-5	48	27	59	33	69	38	176	97.2
6-10	0	0	0	0	1	1	1	0.6
11-20	0	0	0	0	1	1	1	0.6
21+	2	1	1	1	0	0	3	1.7
Experience with Technology								
Strongly Agree	30	17	40	22	36	20	106	58.6
Agree	11	6	18	10	27	15	56	30.9
Neither	5	3	2	1	6	3	13	7.2
Disagree	4	2	0	0	2	1	6	3.3
Strongly Disagree	0	0	0	0	0	0	0	0.0

Course Delivery

The research design for this study was based on comparing delivery methods and learning elements across three different groups. Additionally, this research design provided the opportunity for all participants to take one CBT that had been augmented with the different tools and techniques. The delivery of the courses and the recall quiz used for this study is described within this section.

CBT Course Delivery

The version of the CBT course used throughout this study was released in October 2021 and since its release over 29,000 units have been delivered. The overall safety council passing rate has been 84% for this course for the past two years. The course has been reviewed by industry SMEs and has been updated throughout the years based on changes to federal or state regulations, specific needs or accepted practices within the industry, and continuing reviews by SMEs. The course focuses on confined space awareness and was designed using Articulate 360 e-learning development software. All participants in this study, regardless of group, completed this course.

Of the 634 participants who consented to be a part of the study: (a) 237, or 37% of these participants were randomly assigned to take this course without VR or emotionally resonant videos, titled CS, (b) 201, or 32% of the total number of consenting participants, were randomly assigned to take the confined space course that included the CBT course with VR exercises which was titled CS-VR, and (c) 196, or 31%, were randomly selected to take the course that included VR exercises and emotionally resonant videos, CS-VR-V.

All data collected on the participant's course exams were stored in the safety council LMS and subsequently uploaded to IBM SPSS Statistics software version 29.0.0.0 (241) to assist in the statistical analysis. Demographic information provided by the learners during the course delivery was saved to the safety council's LMS and uploaded to SPSS software. The participants' course exam scores were specifically designed to produce a whole number score from 0–100 inclusive.

Recall Quiz

Three days following the course completion a five-question quiz was sent to each participant's mobile phone number regardless of which group the participant was in. Throughout the study 634 recall quizzes were sent to participants who consented to be a part of the study, and 181 participants, or 29%, completed the recall quiz.

All participants regardless of treatment were told to expect the quiz and were encouraged to complete the quiz when it was delivered. A reminder text was sent to the learner's smartphones via SMS one day following course completion to establish contact with the learner and help influence learners to complete the recall quiz. A follow-up reminder was sent at least seven days after course completion to any learners who had not completed the quiz. Reminder notifications were configured such that only one extra reminder was sent to any participant.

Any participants who completed two recall quizzes had their second quiz results removed from the data analysis. Any participants who completed the quiz after September 23rd, 2023 were not included in the data analysis. Any participants who did not complete all five questions of the quiz were not included in the data analysis.

Data Processing

The sample data was processed as described below prior to analysis to ensure that the data offered the researcher the best opportunity to understand the results of the study. Any participant who did not agree to be a part of the study by accepting the informed consent form was removed from the sample data. Data from participants who did not fully complete the recall quiz were removed from the sample data before analysis. Data from participants who failed the course exam and took the any course twice, regardless of group, their second attempt was removed from the sample data. These participants' recall quiz scores were removed from the data for analysis to guard against the learning effect affecting the data or results. There were 31 of these failing scores, or 9%, within the 634 consented participants. Finally, for participants who answered the recall quiz scores twice, the scores from their second attempt were removed from the data set to ensure that learning did not occur during the recall quiz due to the testing effect or practice effects, a factor that can negatively affect internal validity.

Irregular Course Delivery

At any time during the delivery of the courses, regardless of which group the participant was assigned to, participants could stop the course to take a break or ask a proctor if they had questions. Any participant who took a break was identified using a valid picture ID and their council registration form before returning to continue the course. If the participant took a break in the middle of the course, they were able to continue training from approximately the same place in the course where they left upon their return due to the bookmarking capability of the course delivery software. The only parts of the courses where taking a break was not allowed were once the participant started the course exam or during the VR exercise or delivery of the emotionally resonant video. Any participant who had to take a break during the VR exercises or the emotionally resonant video had to return to the beginning of the VR exercise or video and start that exercise again. Any participant who took a break during the course exam had to restart the course from the beginning and their information was removed from the data for analysis to guard against practice effects. There were no reported incidents of either of these occurring.

Participants who were uncomfortable with VR training were provided the opportunity to take CS and their data was removed from the data for analysis. The proctors identified four learners who asked to not take the VR course they were randomly assigned to. The data from these four individuals, less than 1%, were removed from the data for analysis to guard against the effects of self-selection within the sample. There were no participants who expressed that they felt a feeling of motion sickness in the CS-VR or CS-VR-V groups.

Results

The dataset was prepared for analysis by assigning numerical codes to all three groups: (a) CS = 1, (b) CS-VR = 2, (c) CS-VR-V = 3 in SPSS. Demographic and variables regarding experience were coded into SPSS as nominal scale variables and assigned numbers where appropriate in order to complete the analysis. This coding process allowed for an efficient and structured data analysis. A one-way ANOVA was used to analyze the effects of the CS-VR and CS-VR-V treatments on the participants' learning outcomes.

This analysis addresses the following research question:

- Do differences exist in knowledge retention for contractors from the following three groups: those who completed confined space courses with VR and emotionally resonant videos, those who took confined space courses with VR, and those who completed confined space courses without VR and without emotionally resonant videos?

Hypothesis

In order to answer the research question, this study used a null hypothesis and alternative hypothesis. This study tested the following null hypotheses based on the research question:

Ho. There is no difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

The alternative hypothesis for this study was:

Ha. There is a difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos.

With regard to the research question, this study found that there was no statistically significant difference in knowledge retention for either participants who completed confined space courses with VR and emotionally resonant videos or participants who completed confined spaces courses with only VR and no emotionally resonant videos compared to those who completed confined space courses without VR and without emotionally resonant videos, $F(2,178) = 1.77$, $p = .173$, $\eta^2 = 0.020$.

The mean score on the recall quizzes for participants who took CS (M = 70.4%, SD = 21.47) which had no VR nor emotionally resonant video elements was less than the mean score for participants who took CS-VR-V (M = 76.90%, SD = 21.02) which included both VR exercises and emotionally resonant videos, but was not statistically significant. Additionally, although the mean score on recall quizzes for participants who took CS-VR (M = 76.67%, SD = 18.83) which had only VR elements, was greater than the mean score of participants who took CS (M = 70.4%, SD = 21.47) which had no VR or emotional video elements, the results were not statistically significant. The mean scores on recall quizzes by group are shown in Table 4.4.

Table 4.4. Means and Standard Deviations on Recall Quiz Results by Group

Group	*n*	Recall quiz score *M*	*SD*
CS	50	70.40	21.47
CS-VR	60	76.67	18.83
CS-VR-V	71	76.90	21.02

Note. The maximum score is 100.

Detailed Analysis

Running Levene's test of equality of variance is used to ensure that the data has met the underlying assumption of homogeneity of variance. When the data from this study was tested against Levene's test of equality of variance in SPSS, the significance value (p = .118) was greater than the alpha (α = .05) indicating this data's variance and error variance were equal across all groups and the underlying assumption of homogeneity of variance was met. A test of between-subject effects helps to make a decision to reject the null hypothesis based on the partial eta squared value. The partial eta squared value for the data from recall quiz score participants (η^2 = 0.020) indicates that there was a minimal effect of the CS-VR and CS-VR-V treatments on the recall quiz scores.

While this study showed that for the entire sample, there was no statistical significance between the three groups on the recall quiz results the means on the recall quiz did show that the CS-VR and the CS-VR-V groups tend to inspire greater recall for the participants. The primary dependent variable for this study was the recall quiz data collected three days or more after the course completion. However, another dependent variable, the course exam score, was also collected. This study determined that there was no statistically significant difference in the post-course exam scores among the three groups $F(2,178) = 0.300$, $p = .741$, $\eta^2 = 0.003$. Although the results for the recall quiz were not significant there was a change in the means when compared to the means on the course exam. While course exam means were approximately equal across all groups, there was a difference in means that favored the CS-VR and CS-VR-V groups as shown in Table 4.5.

Table 4.5. Descriptive Overview of Recall Quiz and Course Exam

Measure	CS		CS-VR		CS-VR-V		$F(2,178)$	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*		
Recall Quiz	70.40	21.47	76.67	18.83	76.90	21.02	1.77	0.020
Course Exam	92.80	6.71	92.00	6.03	92.00	6.01	0.300	0.003

Note. The maximum score is 100.

This suggests that the course delivery method and the elements of VR exercises or emotionally resonant videos had little to no effect on the post-course exam mean scores between participants immediately after taking the course, but that these elements might benefit participants' recall, although a non-statistically significant one.

Exploratory Analysis

Investigating the statistical relationships between the groups further, excluding subsets of data from different demographic and experience-related variables yielded statistically significant results when investigating age and experience. When participants who were 18–24 years old (n = 46) were not included in the analysis there was a statistically significant result $F(2,132) = 3.16$, $p = .046$, $\eta^2 = 0.046$. Descriptive statistics for this data set are shown in Table 4.6.

Table 4.6. Recall Quiz Descriptive Statistics Excluding Youngest Participants

Group	*n*	*Mo*	*Mdn*	*M*	*R*	*Min/Max*	*IQR*
CS	45	60 (16)	80	70.67	80	20/100	60 - 80
CS-VR	40	60, 80 (13)	80	75.00	80	20/100	60 - 100
CS-VR-V	50	80 (20)	80	81.20	80	20/100	80 - 100

Note. The maximum score is 100, Mo = mode, Mdn = median, R = range, IQR = interquartile range.

The same relationship between course exam means and recall quiz means was found in this more limited set of results as shown in Table 4.7. Course exam means for these results were approximately equal across all three groups, indicating that course delivery elements again did not affect immediate recall, while recall quiz means favored the CS-VR and CS-VR-V groups.

Table 4.7. Means of Recall Quiz and Course Exam Excluding Youngest Participants

Measure	CS		CS-VR		CS-VR-V		*F*(2,132)	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*		
Recall Quiz	70.67	21.15	75.00	21.12	81.20	19.55	3.156	0.046
Course Exam	92.44	6.78	92.00	6.66	93.12	6.21	0.337	0.005

Note. The maximum score is 100.

In terms of experience, when participants who had less than 5 years of experience (n = 85) were not included, there was also a statistically significant result $F(2,93) = 3.10$, $p = .050$, $\eta^2 = 0.063$. Investigating this relationship further by performing a pairwise comparison of the data yields that the significance between CS and CS-VR-V is a statistically significant value ($p = .044$). Descriptive statistics for this set of data is shown in Table 4.8.

Table 4.8. Recall Quiz Descriptive Statistics Excluding Least Experienced Participants

Group	*n*	*Mo*	*Mdn*	*M*	*R*	*Min/Max*	*IQR*
CS	32	60 (13)	70	71.88	80	20/100	60 - 80
CS-VR	27	80 (10)	80	78.52	80	20/100	60 - 100
CS-VR-V	37	100 (16)	80	83.78	80	20/100	80 - 100

Note. The maximum score is 100, Mo = mode, Mdn = median, R = range, IQR = interquartile range.

The same relationship between course exam means and recall quiz means was also found in this more limited set of results of experienced participants as shown in Table 4.9.

Table 4.9. Means of Recall Quiz and Course Exam Excluding Least Experienced Participants

Measure	CS		CS-VR		CS-VR-V		$F(2,93)$	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*		
Recall Quiz	71.88	20.23	78.52	20.70	83.78	18.76	3.102	0.063
Course Exam	92.38	6.91	93.33	6.08	93.95	6.16	0.520	0.011

Note. The maximum score is 100.

Despite the statistical significance of these two sets of data, the effect size in both cases is small. This indicates that although there was statistical significance with these more limited results, the magnitude of the difference is minimal.

Finally, an analysis was performed that investigated VR delivery and non-VR delivery without considering if the VR delivery included the integration of emotionally resonant videos. The descriptive statistics for this analysis is shown in Table 4.10.

Table 4.10. Recall Quiz Descriptive Statistics for VR and Non-VR Delivery

Group	*n*	*Mo*	*Mdn*	*M*	*R*	*Min/Max*	*IQR*
Non VR	50	60, 80 (16)	80	70.40	80	20/100	60 - 80
VR	131	80 (49)	80	76.79	80	20/100	60 - 100

Note. The maximum score is 100, Mo = mode, Mdn = median, R = range, IQR = interquartile range.

When the data was organized to analyze the VR and non-VR delivery, the data was not statistically significant $F(1,179) = 3.56$, $p = .061$, $\eta^2 = .019$. The same relationship between immediate recall and delayed recall using course exam means and recall quiz means was found using this data as well as shown in Table 4.11.

Table 4.11. Means of Recall Quiz and Course Exam for VR and Non-VR Delivery

Measure	Non-VR		VR		$F(2,93)$	η^2
	M	*SD*	*M*	*SD*		
Recall Quiz	70.40	21.47	76.79	19.97	3.56	0.019
Course Exam	92.80	6.71	92.00	5.99	0.603	0.003

Note. The maximum score is 100.

Summary

This chapter describes the analysis of the data that was collected during the proposed study. An overview of the sample that participated in the study was provided including information that would help to show that the sample provided data that was consistent and distributed normally across all three groups. Information on the demographic and experience variables that were a part of that sample were provided as well as the researcher's analysis of any outlier information or where this variable information might affect the results and analysis. Information on the ANOVA analysis, whether or not the overall data was significant, as well as the effect size was provided. Finally, a series of ANOVAs were provided on the data by manipulating different factors such as the demographic and experience variable information and the delivery method.

Chapter 5 - Discussion, Recommendations, and Conclusions

This study explored the effects of different technologies for training delivery to analyze learner recall and the likelihood of transfer of learning for energy industry contractors. Specifically, this study used a CBT course augmented with VR exercises and emotionally resonant videos to determine if courses that include these learning tools and techniques could offer energy industry contractors a better chance for long-term transfer of learning.

To achieve this, the study investigated the differences in recall between participants who completed training in three distinct groups: (a) CS, participants who took a traditional CBT, (b) CS-VR, participants who took the traditional CBT augmented with VR exercises, and (c) CS-VR-V, participants who took the CBT, and VR exercises with emotionally resonant videos. All participants were provided a quiz three days following course completion to measure recall. This chapter provides a summary of the analysis of the data, provides a rationale for the results against the research questions, and discusses the study's limitations and potential future research topics stemming from the results.

Major Findings

This study found the following major findings from the analysis of the data: (a) the application of VR exercises increased the chance for transfer of learning to occur, (b) that the means on recall quiz scores for CS-VR-V were higher than those for CS-VR and CS groups, but that the results were not statistically significant, and (c) a statistically significant relationship exists for recall quiz scores when experience and age variables were manipulated to exclude the least experienced and the youngest participants. These three findings are described below.

Based on the data, the application of VR, regardless of whether the VR exercises include an emotionally resonant video, has the potential to enhance recall three days or more after the course completion. Although the results for CS-VR and CS-VR-V compared to CS were not statistically significant, the mean recall quiz scores for participants who took either CS-VR or CS-VR-V was higher than the mean recall quiz scores for participants who took the CS course. Broadly put, this study's research question asked whether differences in knowledge retention exist for participants who took these courses. The data show that VR exercises offer learners a better chance for transfer of learning.

This finding is at odds with previous internal studies at the safety council with a similar focus which found a statistical significant relationship between groups (HASC, 2020). A factor effecting the results of this study could be the three-day gap between course delivery and recall quiz delivery. The safety council's previous internal studies included a five-day gap between course completion and recall quiz delivery. Statistical significance was found in those studies with this longer delay between course completion and recall quiz.

Course exams administered immediately after course completion provide means that are approximately equal across all three groups. This implies that VR did not affect immediate recall, but the means from the recall quiz administered three days after course completion favored the courses that included VR exercises. Based on these results this study concludes that after three days there is a greater potential for transfer of learning for those learners who take courses augmented in some way with VR.

Regarding the second major finding from this study, while the results do not show a statistically significant result for participants who took CS-VR-V, the results do show that participants who took the CS-VR-V course scored higher on the recall quiz than those who took

CS-VR or CS. This study's null hypothesis states: that there is no difference in knowledge retention for contractors who completed confined space courses with VR and emotionally resonant videos, or confined space courses with VR, compared to those who took confined space courses without VR and without emotionally resonant videos. Although the data show a lack of statistical significance indicating that knowledge retention and the potential for transfer of learning did not increase substantially, there was a difference in recall quiz means that favored CS-VR-V participants.

Finally, when the youngest or least experienced participants are excluded from the analysis, this study found statistically significant results for recall quiz means. This result provides insight into how different learners process VR exercises and emotionally resonant videos within the courses and the potential effects of cognitive load on contractor learners and the potential for transfer of learning.

Discussion

This section provides a detailed discussion about the major findings listed above. First, a rational for why VR groups performed better on recall quizzes is provided, followed by a discussion of why the CS-VR-V recall quiz score means might be higher. Finally, a detailed analysis is provided illuminating why removing least experienced and younger participants might have led to statistical significance.

Transfer of Learning

This study's primary purpose was to investigate the differences between learner recall for participants who complete traditional CBTs and those who complete CBTs augmented with VR and emotionally resonant videos in order to determine if VR exercises and emotionally resonant videos inspires a greater likelihood of transfer of learning from the training site to the worksite for contractor learners. This study found that the application of VR exercises increases knowledge retention and the chance for the transfer of learning to occur even though a statistically significant relationship was not found.

One primary contention of this study is that new knowledge is constructed based on practice, experience during learning, previous experience and the opportunity for learners to reflect (Hertel & Mills, 2002; Knowles et al., 2012; Kolb, 1984). Cognitive constructivist learning theories specifically are built on the understanding that adult learners analyze and scaffold understanding based on their previous knowledge, and make new mental models based on problem-solving (Powell & Kalina, 2009; Ross-Gordon et al., 2017; Taylor et al., 2000). Numerous studies prove that VR as a training tool can help learners: (a) practice dangerous and complex procedures in a safe environment (Pantelidis, 2009; Pedram et al., 2021; Sankaranarayanan et al., 2018), (b) understand complex procedures through practice and changing perspectives (Bertram et al., 2015; Kamińska et al., 2020), and (c) make use of memory cues to enhance memory development (Brown, 2014; Cooper et al., 2021; Herz, 2021). This study aimed to use memory cues through: (a) cognitive learning theories, (b) constructivist learning theories, (c) emotion, and (d) immersiveness to help encourage greater likelihood of transfer of learning.

The recall means for CS-VR and CS-VR-V were higher than the recall means for CS. This tends to support the constructivist learning principles described in this study that apply to both the CS-VR and CS-VR-V courses. Other studies that relied on similar methodologies found a similar relationship to the one found in this study (Barsom et al., 2020; Harman et al., 2017; Kamińska et al., 2020; Mystakidis et al., 2022). Despite a lack of statistical significance across the entire sample, these results have implications for the effectiveness of integrating VR technology and the use of video delivery of emotionally resonant case studies into traditional CBTs for increasing the potential for transfer of learning. In every finding, the course exam means taken immediately after course completion were approximately equal, while the means for CS-VR and CS-VR-V were higher after three days. This suggests that VR in general provides a greater potential for inspiring transfer of learning for these course takers.

Additionally, this study found that the means on recall quiz scores for CS-VR-V specifically were higher than the recall quiz scores for participants who took either CS-VR or CS. The CS-VR-V course used in this study was designed to help adult learners develop more memory cues through: (a) experiencing a situation, (b) having an opportunity to experience simulated exercises and experiences, (c) remediating their mistakes, (d) applying meaning to those simulations by watching a relevant video, and (e) reflecting on the effects of those experiences when watching other contractors go through a similar situation. The development of memory cues dealing with greater emotional appeal through the emotionally resonant video and narrative storytelling should have helped participants develop more memory cues and inspire a greater likelihood for recall and transfer of learning.

The emotionally resonant video that was a part of the CS-VR-V course was designed to create an emotional response for the learner and provide more well-developed and durable memories through the development of memory cues through emotion and narrative storytelling (Anderson & Shimamura, 2005; Hirst & Phelps, 2016; Steffes & Duverger, 2012). Although not statistically significant, the CS-VR-V recall quiz means were higher than the CS group and marginally higher than the recall means of the CS-VR group. This slight increase in the recall quiz score for CS-VR-V course participants can be attributed to the emotionally resonant videos that were included within the CS-VR-V group. The increase found for CS-VR-V compared to

CS can be attributed to the addition of both the VR exercises and the emotionally resonant videos that were used in the CS-VR-V course.

Emotional moments can create deeper meaning and more durable memories for learners (Dirkx, 2001; Lazarus, 1991, Tyng et al., 2017). Triggering an emotional moment during learning, as this study hoped to do with the video in the CS-VR-V course, should have provided the dual benefit of impacting the learner's degree of attention as well as inspiring more focused memory development. Studies of adult learners have found that while the hippocampus is integral in the encoding of event memory, the emotional elements within CS-VR-V were designed to activate the amygdala as well, which is critical for emotional memory construction (Hamann et al., 1999; McGaugh, 2004; Phelps, 2004). In terms of emotion and transfer of learning, Haskell (2000) writes that the more meaning and feeling that a learner applies to their learning, the greater chance there is for transfer of learning. The fact that the CS-VR-V group's recall quiz score means were greater than the recall means of both the CS group and the CS-VR group indicates that emotion provided a deeper, more meaningful memory development process for CS-VR-V participants.

The focus of this study was on increasing the likelihood of transfer of learning for contractor learners. The fact that participants who took courses with VR exercises, and those with VR exercises and emotionally resonant video performed better on recall quizzes three days following the course completion is indicative of a greater likelihood of transfer of learning for participants who took those courses. When the course exam scores, which show approximately equivalent means immediately after the course, are included in the analysis, the tools used in the experimental groups to increase the likelihood of transfer of learning and increase the potential number of memory cue points, seem to have had the desired effect. Although the results are not statistically significant, there is a greater likelihood for transfer of learning for contractors when VR exercises and VR exercises with emotionally resonant videos are utilized.

Cognitive Load Theory

The data from the participants' demographic and experience variables was analyzed in an effort to better understand the results of the recall quiz. This study found a statistically significant result when experience and age variables were manipulated to remove the least experienced and the youngest participants from the recall quiz scores. This could indicate that the youngest and least experienced participants lacked the necessary expertise and prior experience to effectively develop memories, scaffold understanding, build new understanding on top of previous experience while absorbing information through the multitude of different media and delivery elements.

Knowles et al. (2012) write that crystallized intelligence is more beneficial for future learning and that prior experience can influence and effect learning. Their finding and the results of this study help to confirm the cognitive constructivist learning theory that adult learners analyze and scaffold understanding based on their previous knowledge (Ross-Gordon et al., 2017; Taylor et al., 2000), and create more well-developed and complex schemas through their experiences and expertise (Sweller et al., 1998; Sweller et al., 2019).

Cognitive load theory is a factor addressed by many researchers in terms of multimedia instructional design (Fisher et al., 2019; Mayer, 2020; Sweller et al., 1998; Sweller et al., 2019; Um et al., 2012) as well as in VR simulations (Albus et al., 2021; Breves & Stein, 2023; Makransky & Petersen, 2021). Several studies investigated prior to this study found results that indicate VR's potential to overwhelm a learner's mental resources especially as related to memory development and processing (Bailey et al., 2012; Fisher et al., 2019; Parong & Mayer

2018). The contention that there is a limited cognitive capacity that learners can call on is shown in the study by Bailey et al. They contend in their study that the limitations they found in their participants were due to the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP). the LC4MP model contends that adult learners must limit their cognitive abilities to certain information when there is too much information to be processed at once (Ahn et al., 2022; Fisher et al., 2019). Fisher and Weber (2020) write that "individuals must prioritize (either consciously or unconsciously) certain information streams over other ones during message processing in order to manage their limited resources while still achieving their goals" (p. 2). The authors go on to state that the LC4M model provides a lower chance of memory retrieval when there are negative or limited resources available.

Makransky and Petersen (2021), discussing learner's expertise, state that "learners with high prior knowledge are less affected by additional extraneous load induced by variations in the learning environment" (p. 620). Sweller et al. (1998) focus on how more prior knowledge leads to the development of a more complex schema which can lead to greater availability of working memory resources. They state:

> Intellectual skill comes from the construction of large numbers of increasingly sophisticated schemas with high degrees of automaticity. Schemas both bring together multiple elements that can be treated as a single element and allow us to ignore myriads of irrelevant elements. Working memory capacity is freed, allowing processes to occur that otherwise would overburden working memory. (p. 258)

This ability of more experience to free up working memory resources can help explain the results of this study that found a statistically significant result for older and more experienced participants when taking recall quizzes. Not only have older and more experienced learners had more opportunities to work in confined spaces, but they have also taken regulatory training more often. This expertise and previous experience, according to Sweller et al. (1998) would lead to more well-developed and complex schemas and free up working memory resources.

Participants with more experience in the industry and with confined space work would naturally will have more complex, well-developed schema regarding this type of work. Although not a requirement by OSHA, technicians, supervisors, and other contractor field workers who work in the energy industry take confined space courses as an annual requirement placed on them by the sites they visit and their own organization's training requirements (Bannen, 2009; NASP, 2020; Team Safesite, 2020). Additionally, these contractors must take site specific training courses for every site where they might work. Those facility owners who have sites that include confined spaces must include a section of their site-specific training course on how to work within those confined spaces (OSHA, 2015). Experienced contractors within the energy industry may be exposed to multiple courses and information on confined space processes, procedures, and hazards every year and thus build up a far more in-depth schema and understanding about this work scope. It is these schemas that free up working memory load for learners, Sweller et al. (1998) contend.

Sweller et al. (1998) write that cognitive load theory encapsulates three different types of cognitive load, including: (a) intrinsic cognitive load, (b) extraneous cognitive load, and (c) germane cognitive load. Intrinsic cognitive load is characterized by the difficulty and complexity of the learning material. In the case of this study that might be the processes, the procedures, and terminology involved with confined spaces. Extraneous cognitive load is usually expressed as the processes that are not directly involved in learning but might distract or pull the learners attention away from the learning. In the case of this study that could be the emotionally-resonant video, the VR exercises, animations, other learning tools. Germane cognitive load is the effort needed by the learner to created and develop memories of the learning. This is the memory development based on the learning that the learner experiences.

When considering this in the aspect of this study, learners with less experience would be required to use more resources in terms of intrinsic cognitive load to understand and make sense of the new procedures, terms and process that they are confronted with. Sweller et al. (2019) expresses the fact that all three aspects of cognitive load work with respect to one another and can limit the ability for working memory to process and develop learning into in-depth schema. Sweller et al. write that germane cognitive load and extraneous cognitive load can limit working memory that otherwise might be allocated to deal with intrinsic cognitive load. Specifically, they state that the "more resources that must be devoted to dealing with extraneous cognitive load the less will be available for dealing with intrinsic cognitive load and so less will be learned" (Sweller et al., 2019, p. 264). This effect has been found in multiple studies on VR and cognitive load. Han et al. (2021) write regarding the effects of cognitive load on their immersive VR results that their participants were hindered by limited working memory resources in the more immersive VR environments which resulted in negative results that they attribute to increased cognitive load. Frederiksen et al. (2019) found a similar result in their VR study when they found that the more immersive VR environment created greater demands on the cognitive load of novices compared to experts due they believe to the more complex environment leading to increased extraneous load.

This study found similar results that seem to support not just the studies of cognitive load theory in immersive VR environments, but that also substantiates the relationship that Sweller et al. (1998) and Sweller et al. (2019) express in their reviews on expertise and cognitive load.

Implications

The implications of this research can aid safety professionals as well as instructional designers within the community of learners that the safety council supports. First, this study validates that integrating VR exercises into traditional CBT-style training for this community of learners is a valid and worthwhile endeavor. Secondly, the results tend to show that the trends in safety training toward personalizing safety and using an emotional appeal have some worthwhile benefits. Finally, this study finds that this community of learners still needs to adapt to VR technology in order to make full use of this training dynamic.

Integrating VR into Standard Couse Delivery

The fact that the results are statistically significant when younger or less experienced participants are excluded from the analysis should indicate to instructional designers that they must consider cognitive resources and the importance of properly scaffolding information when developing courses for younger or less experienced safety council learners. Based on these results it would seem to make sense for instructional designers to include VR exercises and VR exercises with emotionally resonant videos in their courses if they are trying to promote a greater likelihood of transfer of learning for the contractor learner, but that a three-day delay to measure recall may not be long enough to see a distinct or dramatic improvement.

Using Emotion in Safety Programs

The community of learners that the safety council supports has safety initiatives that utilize programs and initiatives similar in nature to the emotionally resonant videos that this study used (Berry, 2020; Chen, 2016). The results of this study show that there was a slight benefit to using emotionally resonant videos over courses without emotionally resonant videos. These results suggest that using techniques like these might have potential benefits, but that relying on them significantly or without other programs and initiatives might be less than worthwhile.

VR for Safety Training

Finally, a byproduct of this study was discovering to what degree this community of learners is used to and has made use of VR in training. An overwhelming number of participants from this sample had no previous experience with VR technology and will need more experience with this technology before it can be fully utilized for training and learning purposes. Extraneous cognitive load demands on working memory resources could be decreased by learners having had more experienced in VR environments, or when VR environments are properly constructed to meet these learners needs (Albus et al., 2021; Frederiksen et al., 2019). Owners and manufacturing sites within the energy industry make use of VR and find benefits from these resources for their worksites and operators (AFPM, 2020; Benedict, 2019; Colombo et al., 2014; Juricic et al., 2015; Taylor, 2022). This study helps to shed light on the fact that the contractor community lags behind in this training capability compared to the operators on the sites that they service.

Recommendations for Future Research

VR has already demonstrated its potential to enhance various aspects of education, from engagement and retention to simulation and visualization. Understanding how VR technology influences learning outcomes is both qualitative and quantitative. A qualitative study might bring to light the challenges that learners have with VR equipment or their perceived reactions to the emotionally resonant video. Additionally, the results from the recall quiz show that a greater number of responses were returned from those participants who took the CS-VR-V course than from the CS-VR course and the CS course. A qualitative study might be able to determine if emotionally resonant videos inspire learners within this learning community to respond to study tools to a higher degree and why.

Studies have shown that movement, speed, and activity during training activate more memory-making cells such as place cells, head-direction cells, grid cells, and sensorimotor cells which in turn can create more durable, easily accessible memories (Gatlin, 2014; Krokos et al., 2019; Tuena et al., 2019). Future studies may want to include more activity and motion rather than relying on a seated modality as this study has. While the less active delivery of VR for the participants helped with the administration of the courses to the learning community, particularly for a sample of participants with little experience in using VR, facilitating more activity in the VR environment could lead to greater statistical significance and effect size in the results.

A multitude of studies such as Schott and Marshall (2018), McHaney et al., (2018), and Zapalska et al., (2012) verify the efficacy of Kolb's learning cycle through active learning and reflection in simulations and VR environments. Future research designs based on this study might want to allow participants the opportunity to re-try the VR simulation after participants view the emotionally resonant video. Providing a second opportunity for the learner to act out the processes and procedures after the emotionally resonant video would more closely follow the learning cycle that this study endeavored to follow, that of: (a) concrete experience leading to (b) observations and reflection followed by, (c) formation of abstract concepts and the chance to move to (d) testing these concepts in new situations. Providing learners a second opportunity to practice or test what they have learned in the video by working through the simulation again might help learners fully reflect and test what they have learned and more fully work through the Kolb learning cycle.

A factor that the results of this study have shown is that providing a three-day gap between course delivery and recall quiz delivery may not be a sufficient gap to find statistical significance among the sample groups. Previous internal studies similar to this study used a five-day gap between course completion and recall quiz delivery (HASC, 2020). These studies found a statistically significant relationship for courses that included VR exercises for the entire sample, not just when excluding sub-groups from the sample. It is possible that a longer delay than the three days that this study utilized could yield results similar to those of previous experiments. Future research designs may want to include variable delays in recall quiz delivery to determine if recall and delay have a direct association.

Finally, the results of the exploratory analysis of this study tend to show that cognitive load might have played a role in the potential transfer of learning for younger and the least experienced contractor learners. Future studies might want to provide variable degrees of difficulty or support a research design focused on determining how these tools of VR exercises and emotionally resonant videos contribute to cognitive load for these learners and how this cognitive load could be lessened. A clearer understanding to what degree the least experienced and youngest learners in this community process and retain information could lead to improved safety for the worker and the industrial contractor community.

Summary and Conclusion

This chapter has focused on the analysis of the data that was collected in the study and provided a rationale for some of the results. This discussion not only focused on the results of the analysis from a data standpoint but also took into account the learning community and the demographic and other subsidiary information that was collected as a part of this study. This learning community has not been studied extensively in the past. The learning community who use safety councils of the type used in this study, and who work to support the energy industry have not been thoroughly studied as to how different learning capabilities and delivery systems can provide more effective training and create a better opportunity for transfer of learning to occur. This chapter has provided information not only about the data and results of the study but also sheds light on how this specific learning community interacts with the learning and courses.

This study adds to the body of literature regarding learning outcomes using VR as a teaching and curriculum delivery tool for this learning community that supports the energy industry. Although the final analysis and results used the potential for learning outcomes through recall quiz score comparisons, indicating that incorporating VR technology has no statistically significant impact from a traditional CBT delivery and that VR with emotionally resonant videos had no statistically significant impact either, there were some benefits to using VR and emotionally resonant videos. The effectiveness of VR, like any other e-learning experience, depends on the proficiency of the instructional designers, the development team, the curriculum, and the delivery methods. The fact that when controlling for younger participants and less experienced participants led to a statistical significant result indicates that VR course delivery and development should take these aspects of the learning community into account. Courses that are well-developed with clear learning objectives, active learning strategies, and opportunities for interaction and feedback promote student engagement and have the potential to increase learning outcomes (Freeman et al., 2014; Slavin, 2014).

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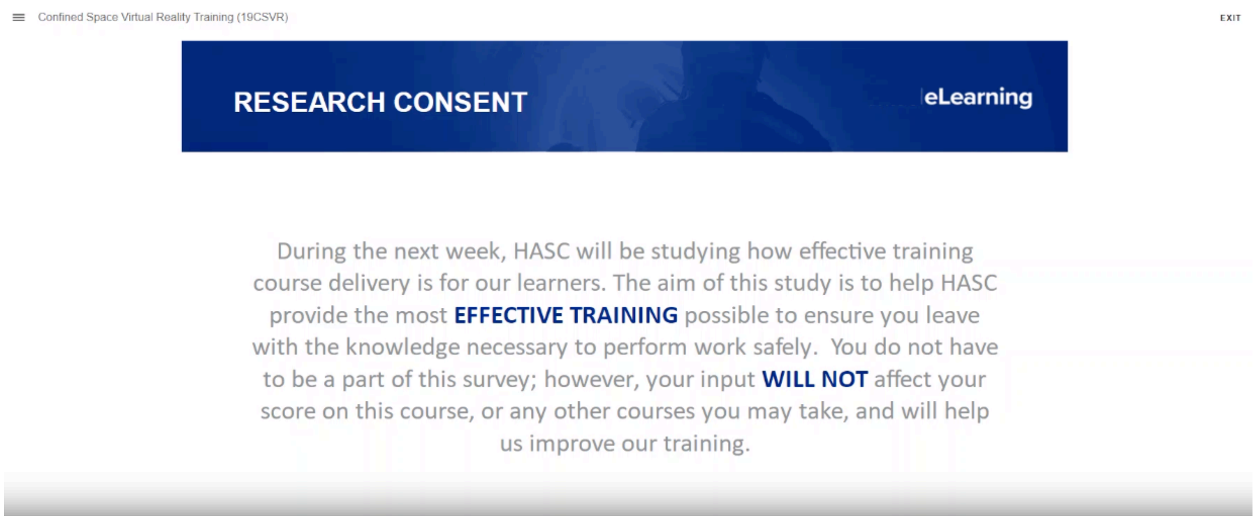
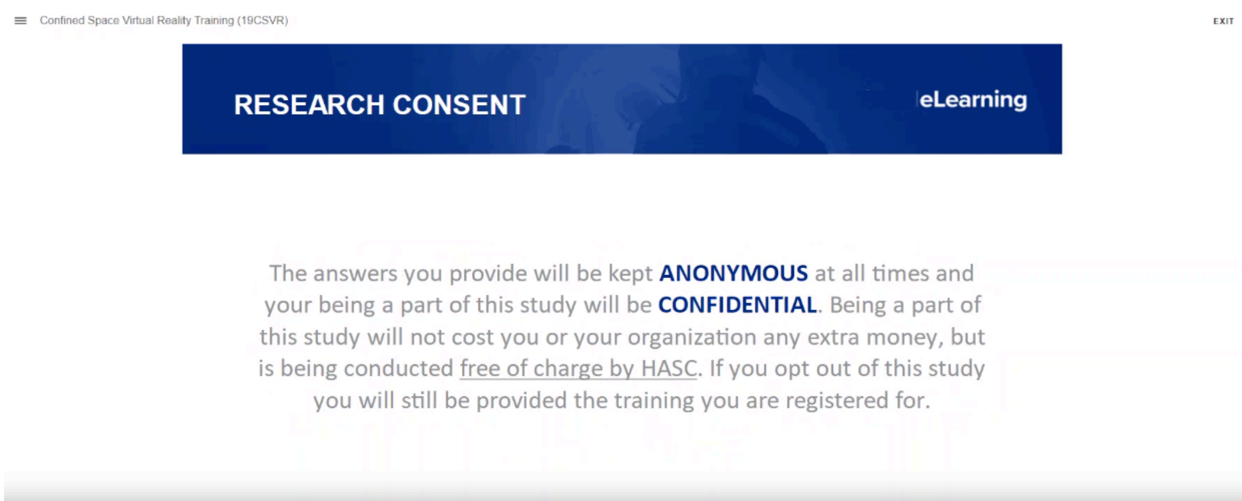
Appendix A - Consent Form

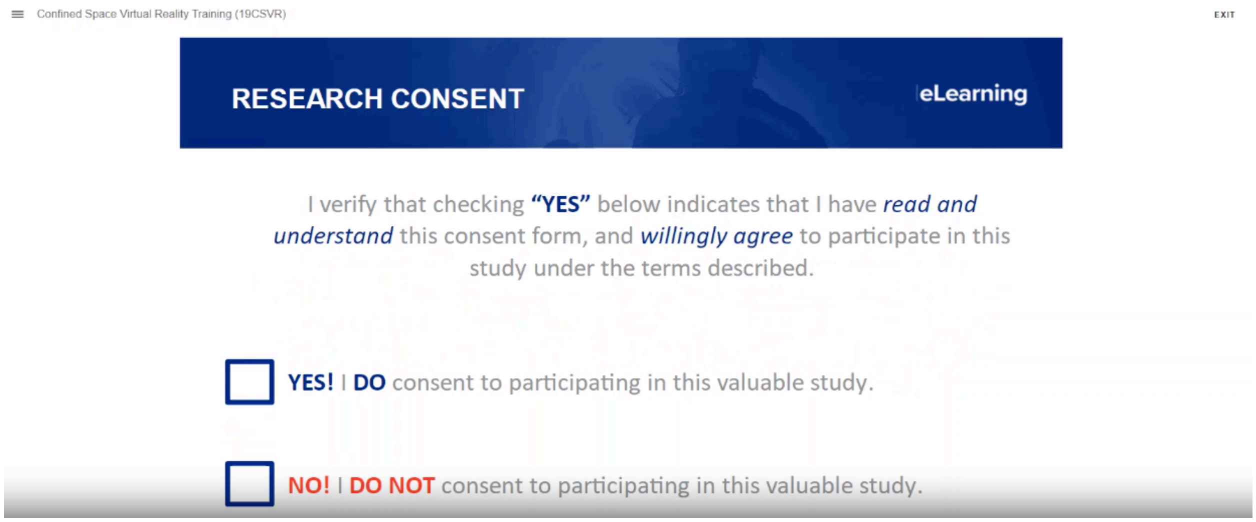
Appendix A Figure A.1



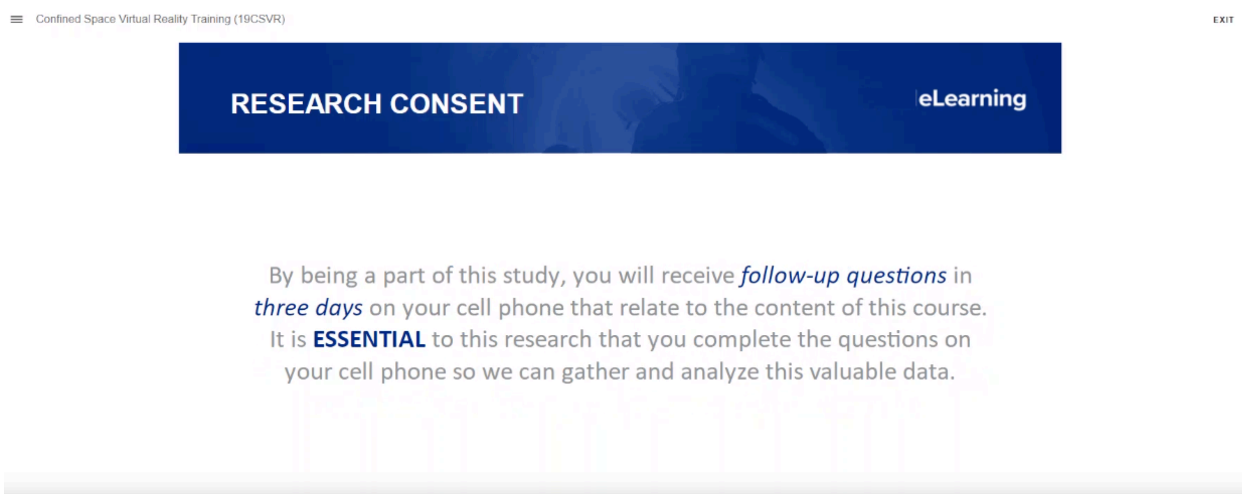
Appendix A Figure A.2



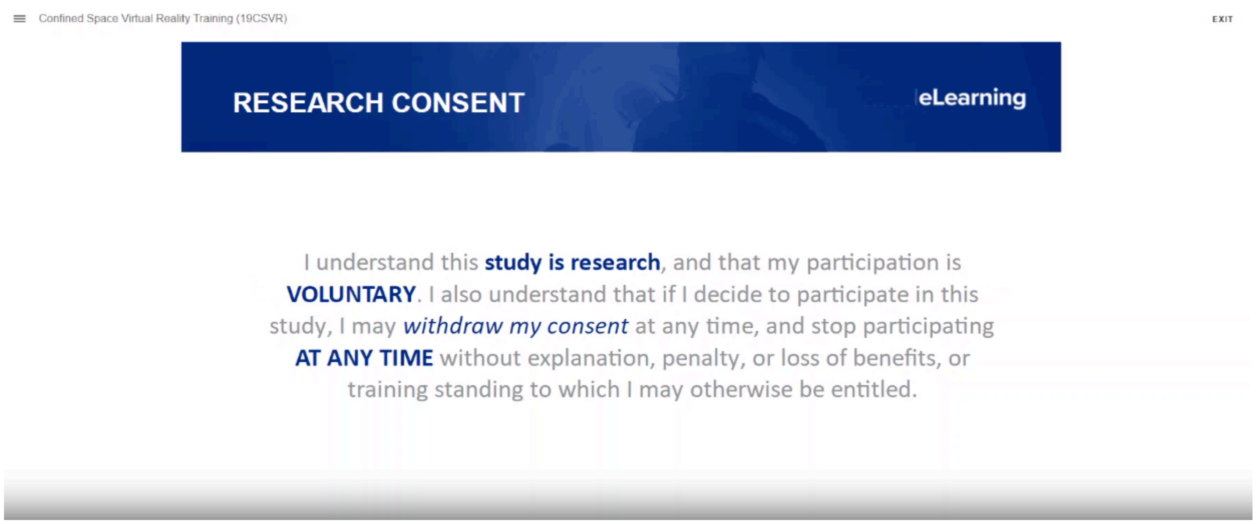
Appendix A Figure A.3



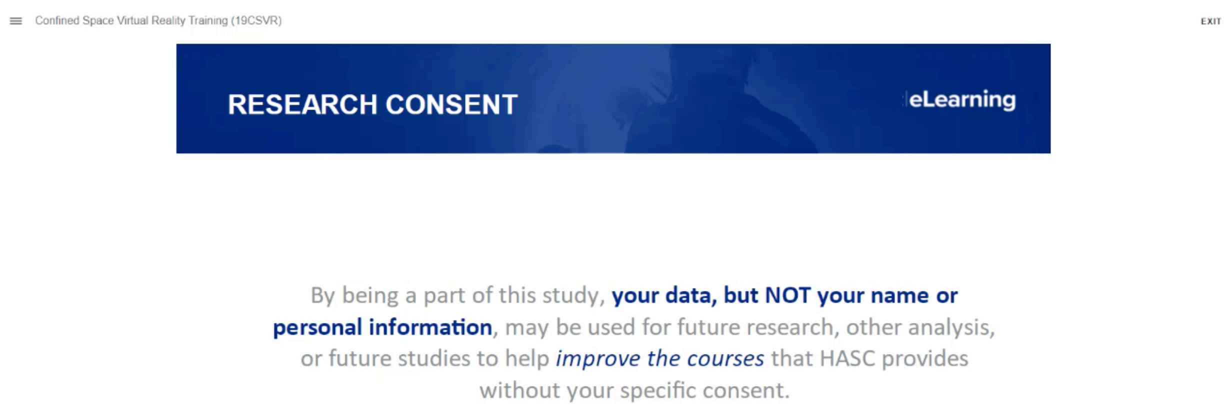
Appendix A Figure A.4



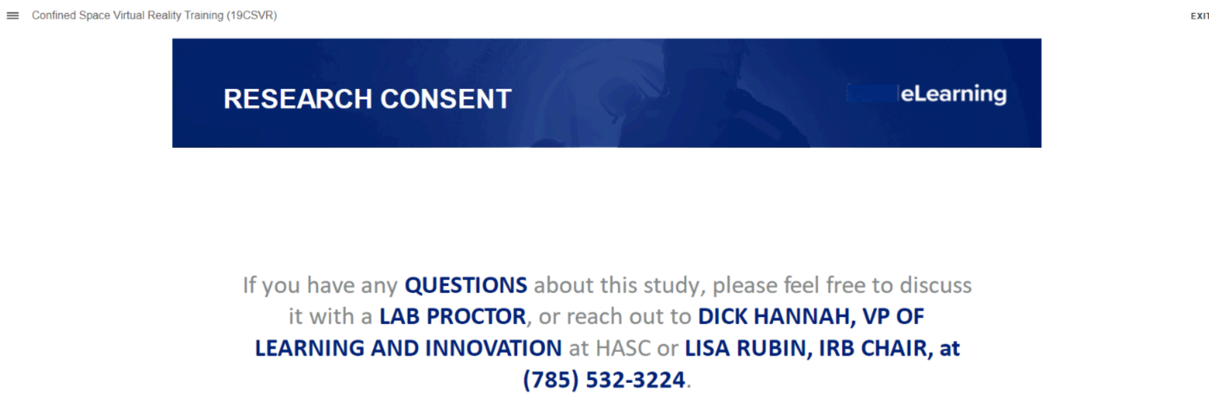
Appendix A Figure A.5



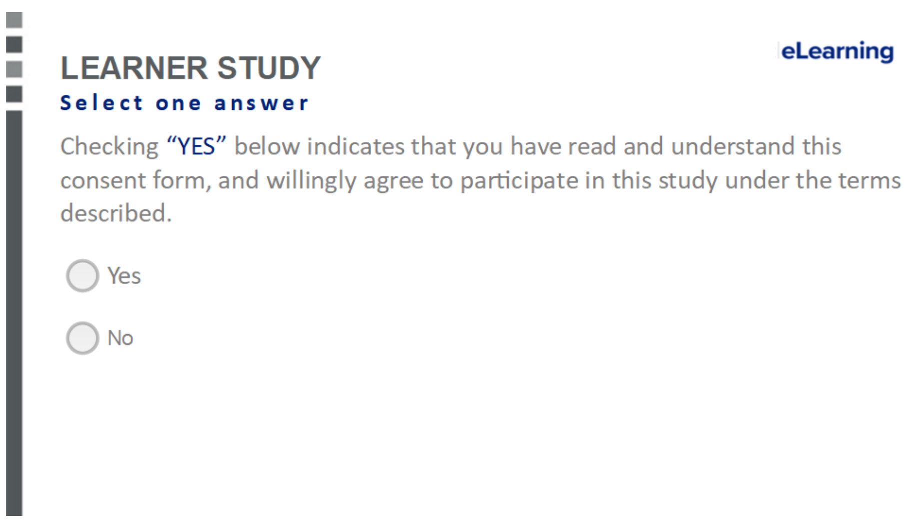
Appendix A Figure A.6



Appendix A Figure A.7



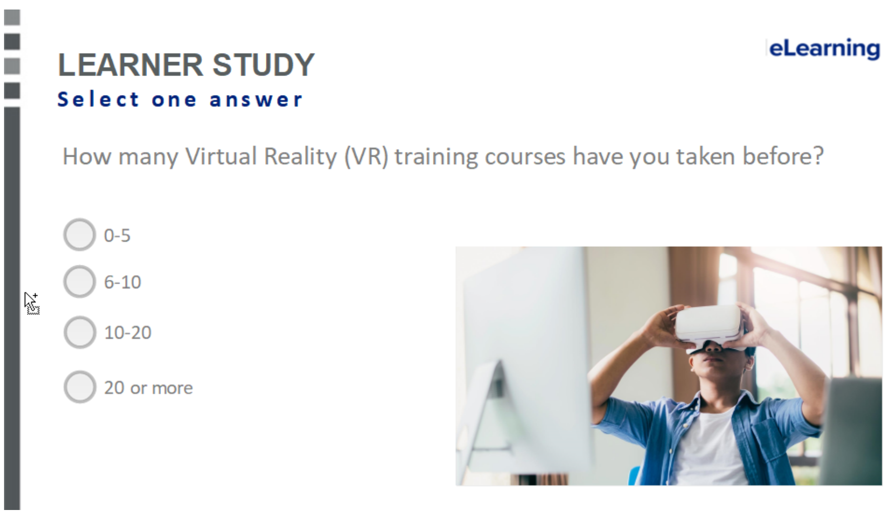
Appendix A Figure A.8



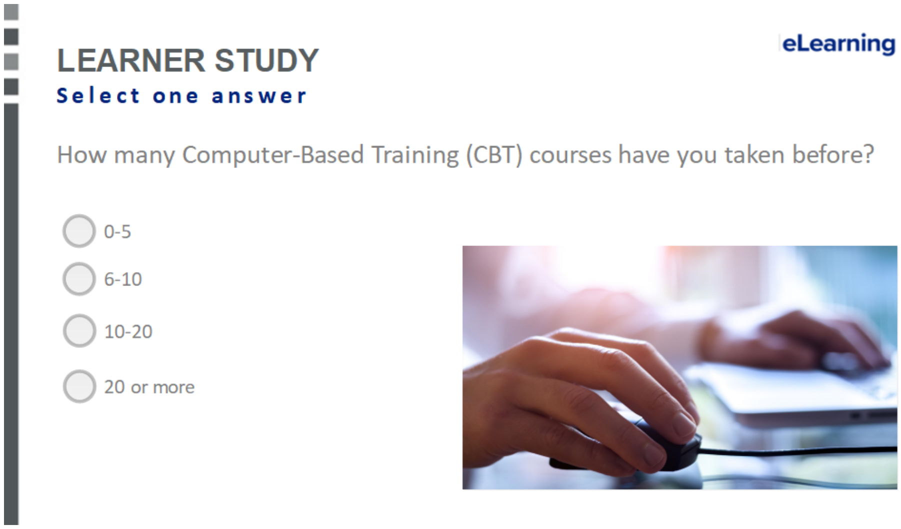
Appendix B - Demographic and Experience Variable Form

Appendix B Figure B.1

Appendix B Figure B.2



Appendix B Figure B.3



Appendix B Figure B.4

Appendix B Figure B.5

eLearning

LEARNER STUDY

Select one answer

Have you acted as a supervisor or leader when performing confined space duties?

- Yes
- No

Appendix B Figure B.6

eLearning

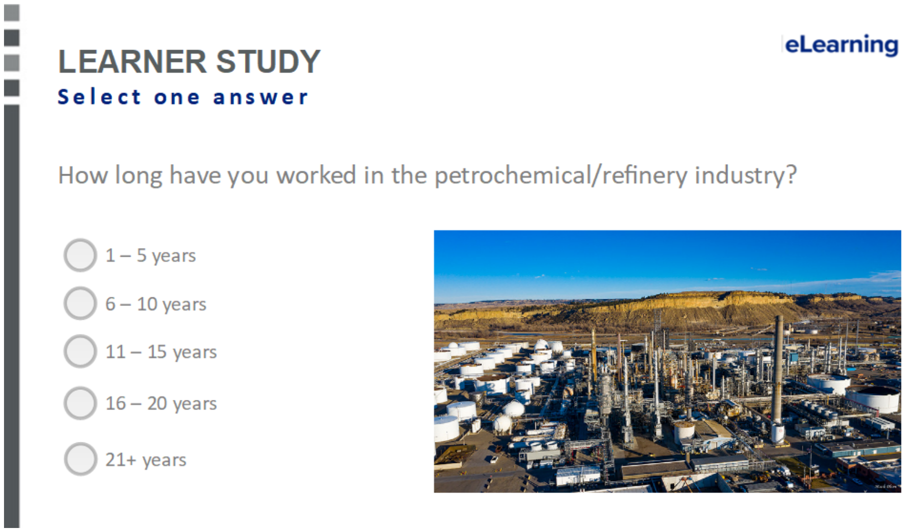
LEARNER STUDY

Select one answer

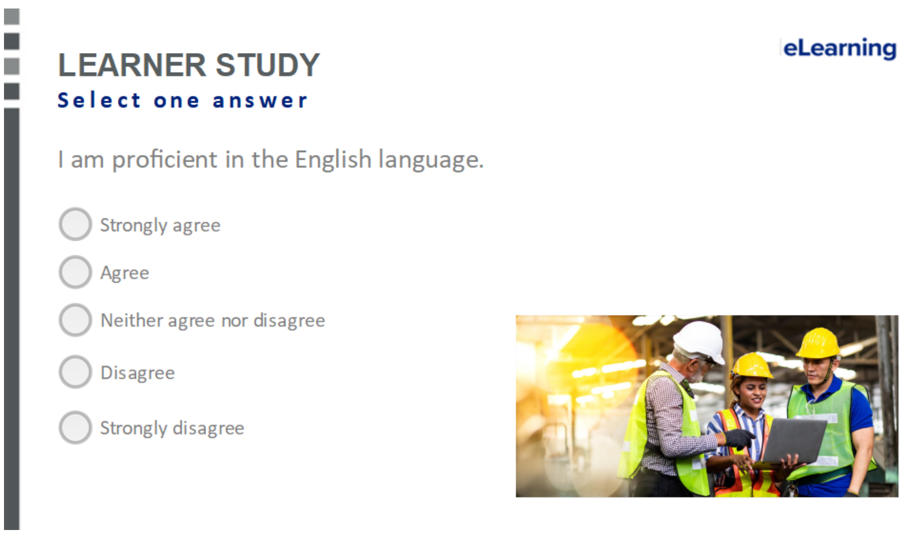
How long have you worked in or around confined spaces?

- 1 – 5 years
- 6 – 10 years
- 11 – 15 years
- 16 – 20 years
- 21+ years

Appendix B Figure B.7

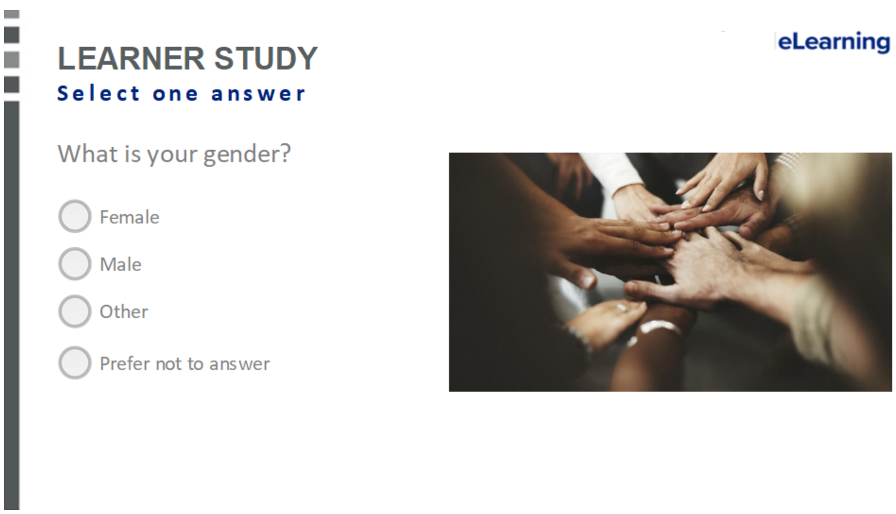


Appendix B Figure B.8



Appendix B Figure B.9

Appendix B Figure B.10



Appendix B Figure B.11

eLearning

LEARNER STUDY

Select one answer

Which category below best describes your age?

- ◯ 18-24 years old
- ◯ 25-35 years old
- ◯ 35-44 years old
- ◯ 45-54 years old
- ◯ 55-64 years old
- ◯ 65+ years old