Research in Learning Technology
Vol. 32, 2024

ORIGINAL RESEARCH ARTICLE

Results of integrating short VR exercises into traditional CBTs

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Received: 29 December 2023; Revised: 11 February 2024; Accepted: 12 February 2024; Published: 15 April 2024

The purpose of this research was to investigate the effects of short virtual reality (VR) exercises on knowledge retention for adult learners at a contractor safety training organisation supporting the energy industry who took computer-based training (CBT) courses. The intent was to simulate a delay period similar to that experienced by contractors who support work in the energy industry to determine if traditional CBT can be made more effective for stimulating greater transfer of learning with the addition of VR exercises. The experimental group was exposed to CBTs augmented by VR exercises that reinforced the CBT course learning objectives. The control group for this research took the same CBT course without short VR exercises. A quantitative analysis was performed on data collected from a course exam provided immediately after the course delivery and from a separate follow-up quiz delivered 3 days after the course(s) completion. Data from these testing instruments were analysed to determine the participant's likelihood of remembering content from the CBT courses and if there was greater knowledge retention of the course learning objectives and procedures within the experimental group than within the control group. The results found a non-statistically significant relationship between the two groups; however, trends between the groups show that there are benefits for transfer of learning when using short VR exercises compared to those groups without short VR exercises.

Keywords: virtual reality; computer-based training; industry

Introduction

Safety skills training and safety compliance training for contractors in the energy industry have traditionally been provided using computer-based training (CBT) courses that leverage computer terminals at safety councils near jobsites. CBT training has several key advantages: (1) it is scalable, (2) it allows for easy and constant verification of the learner's identity throughout course delivery and testing, (3) it provides the opportunity to train large numbers of temporary or new workers to a set standard and (4) it ensures consistency and compliance across multiple sites, locations and workgroups (BIC, 2022). However, for training to be effective, the learner must remember procedures and safety information in the field, not just whilst training at a safety council or training centre. 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

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Citation: Research in Learning Technology 2024, **32**: 3257 - http://dx.doi.org/10.25304/rlt.v32.3257
(page number not for citation purpose)

training for contractor organisations that support the energy industry. Instead, an emphasis has been placed on speedy onboarding and course completion. Learners may spend multiple days taking CBTs at a safety council or training centre and then be expected to perform all the processes, procedures and practices from those CBTs in the field. Spending more time on training, providing hands-on training, or assigning mentors to newly hired employees are not always the most cost-effective methods of training delivery, nor are they worthwhile training techniques for organizations to spend time on if the these techniques do not effectively facilitate the transfer of learning. If using CBTs is a necessary part of training contractors within the energy industry, finding more effective tools to stimulate the transfer of learning is a worthwhile endeavour to improve safety and keep training costs down. Techniques such as providing videos, animations, analogies and other techniques can make CBTs more effective at creating a transfer of learning (Lee & Owens, 2000; Mayer, 2014). Short virtual reality (VR) exercises may also help CBT learners facilitate better learning transfer.

This study investigated the differences between learner recall immediately after and 3 days after course completion for participants who completed traditional CBTs and those who completed CBTs augmented with short VR exercises. The goal of leveraging VR exercises within CBTs is to help learners develop more durable memories and inspire greater transfer of learning. Transfer of learning, put simply, is the opportunity for adult learners to utilise 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). According to Haskell, this transfer of learning is the learner's ability to apply what has been learned in training in another similar, yet wholly different, context.

Haskell identifies six levels of transfer of learning, including (1) non-specific transfer, where learning has a trivial connection to past experiences for the learner, (2) application transfer, where learning is applied to a specific situation, (3) context transfer, where learning is applied in a slightly different context from that in which it was trained, (4) near transfer, which is similar to context transfer, but where learning is transferred to new or similar situations, (5) far transfer, where learning is applied to a new situation and (6) creative transfer, where learning is applied in new ways and where new concepts could be created. This study primarily focused on application transfer, context transfer and near transfer, as these are the levels that closely follow the challenges that contractors face in their work and training.

Many industries are seeing reductions in training costs and time using VR as a training tool (Bailenson, 2020; Holm, 2021; Xie et al., 2021). 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). A study of work practices in petrochemical plants that included both VR 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 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.

Safety training using short VR exercises has two main strengths. First, it can provide learners the opportunity to practice high-risk procedures in a safe, simulated,

Citation: Research in Learning Technology 2024, **32**: 3257 - http://dx.doi.org/10.25304/rlt.v32.3257

realistic environment. It can also help make complex and complicated training more accessible for learners. In her study, Pantelidis (2009) points out that in VR simulations, learners can be put into situations and practice procedures and actions in situations that would be dangerous in real life without sacrificing safety. 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.

VR exercises 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 with reflection to gain understanding (Fenwick, 2004; Kolb, 1984; Merriam & Bierema, 2014). Another critical concept within cognitive constructivist 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 (1) concrete experience to (2) observations and reflection, followed by (3) the formation of abstract concepts and moves to (4) testing these concepts in new situations before starting the cycle again. In terms of this leading to greater transfer of learning, Haskell (2004) emphasises that experience and the adult learner's ability to build on previous experience are crucial for all levels of transfer of learning, including application transfer, context transfer and near transfer.

VR courses also aid in memory development by activating different types of human memory formation: semantic and episodic. Duff et al. (2019) show that declarative memory is composed of semantic and episodic memories, whilst 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, and egocentric frameworks, a self-to-object frame of reference, also play a part in creating more lasting memories in VR. Burgess et al. (2002) and Bird and Burgess (2008) show that activating memory-making platforms for both frameworks can create stronger memories. Burgess et al. (2002), 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. 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 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 are designed to activate sensorimotor involvement and enhance enactment for spatial and episodic memory 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 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).

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 model. This same model can be applied to VR exercises' practice session capabilities. 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 later. 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 later and lead to a more robust transfer of learning for the learner.

Fassbender and Helden (2006) find that learners who developed memories via VR simulations, although not significantly improved immediately after the course, did have greater recall 1 week following the training course. Kamińska et al. (2020) measured the memory encoding and durability of learning objectives in engineering students by testing participants following a 3-day gap. They found that VR participants scored an average of 25% higher on memory tests following a 3-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 found, following a 1-week delay, that the VR condition improved recall.

However, most of the studies reviewed for this research investigate VR simulations compared to non-VR simulations, such as instructor-led training, PowerPoint training or video training (Bailenson, 2020; Bertram et al., 2015; Colombo et al., 2014; Kamińska et al., 2020; Marín-Morales et al., 2019; Xie et al., 2021), but few studies determine how integrating short VR exercises into traditional CBT style training affects the possibility for transfer of learning for contractors. This study is designed to determine how integrating short VR exercises into CBT affects a learner's memory after 3 days.

Method

Since the objective of this research was to investigate the difference between the experimental treatment group's performance 3 days following course completion compared to the control group performance with the same delay, a research question and hypotheses were developed to guide the researchers.

RQ: Do differences exist in knowledge retention for contractors who completed CBT courses augmented with VR exercises and those who took confined space courses without VR exercises?

The null hypothesis for this study was:

> Ho. There is no difference in knowledge retention for contractors who complete CBT courses augmented with VR exercises compared to those who complete CBTs that do not include VR exercises.

The alternative hypothesis for this study was:

> Ha. There is a difference in knowledge retention for contractors who complete CBT courses augmented with VR exercises compared to those who complete CBTs that do not include VR exercises.

This study followed an experimental research design using quantitative data analysis with an independent variable or a randomised experimental treatment with a control group (Bridgmon & Martin, 2013; Creswell, 2013). A five-question follow-up quiz provided 3 days after the completion of the course acted as the post-test measurement instrument to determine the durability of each learner's memory. A 25-question post-course exam provided immediately after course completion with questions completely different than those administered in the follow-up quiz helped the researchers understand the potential degree of transfer of learning from the course without affecting within-group learning. The data acquired from the learner's responses were used to analyse the potential impact short VR exercises had on learner retention and memory durability of procedures and course information. The post-course exam was administered at the computer workstation where the participants took their course(s), whilst the follow-up quiz was delivered via short message service (SMS) technology to the participants' smartphones.

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 CBT course. Learners who were assigned to the control group took the CBT course without VR exercises, whilst learners who were assigned to the experimental group took the CBT augmented with 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.

Confidentiality was maintained for all research participants using processes developed from principles found in Bos (2020). Data were not linked to the participants' names or other identifying information. Data collection began when 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). Study participants' names were not used during the collection, and only the post-course exam scores and follow-up quiz scores were used during data analysis for this research. This information was not linked to the participant's name or safety council ID number at any time after the initial collection.

The safety council has used the CBT course for over 3 years, and over 29 000 units have been delivered. The total expected time to complete the entire CBT is approximately 45 min. The overall safety council passing rate for this course has been 84% for the past 2 years. Industry SMEs reviewed the course, and it 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. It includes videos, animations, interactive exercises and knowledge checks to help learners understand confined space awareness concepts to support the energy industry.

The safety council's instructional designers designed the VR exercises to support the CBT course. Participants in the VR groups had to complete four distinct exercises, including an introduction to VR exercise. The expected time to complete the exercises, including the introductory exercise, is less than 10 min. Participants took the VR courses at the same workstation as the CBT course without changing 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 included (1) audio narration, (2) four timed exercises that support the information provided in the CBT and (3) a virtual space designed to simulate a job site 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 personal computer (PC) based courseware. Seated modality, as opposed to room-scale, was used to best fit established safety council procedures. The VR exercises were designed to last between 3 and 5 min each and were developed to help reinforce confined space knowledge and general practices or procedures. 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 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.

Study participants, regardless of condition, took their courses at a contractor safety council training facility using one of the standard computer terminals used by that council for course delivery. Registrations were completed in the safety council learning management system (LMS) using the safety council's established procedures, and learners were randomly assigned to the control or experimental group by an application designed by the safety council's IT department under the direction of the primary researcher. All of the safety council's computer terminals 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 courses were proctored and assisted in the use of the VR equipment by safety council proctors trained for this purpose. The safety council installed eight computer terminals with Oculus Rift S VR headsets 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.

Citation: Research in Learning Technology 2024, **32**: 3257 - http://dx.doi.org/10.25304/rlt.v32.3257

The safety council proctors also ensured that learners did not cheat, benefit from other learners' information or use aids during the course. Before beginning the study, the safety council proctors underwent rigorous onboarding training and mentoring. This training included 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 during course delivery within the experiment's time frame.

All safety council CBT lab training stations were isolated from neighbouring 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 and spot checks throughout the learner's completion of any CBT. A third-party organisation audits this process annually 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 (1) at the registration desk when the learner entered the safety council lobby and received a training ticket, (2) when the learner arrived at their workstation and (3) 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.

Quizzes were delivered to the participants' smartphones using an established SMS technology that the safety council has used in previous studies. Unlike the course exam delivered immediately after the course delivery, participants were not required to complete the follow-up quiz. Reminders that asked the participants to complete the quiz were sent to the study participants, but only to those who had not been sent a previous reminder. This ensured that participants were sent only three texts: (1) an introductory text to encourage the learner to use the link, (2) the recall quiz questions and (3) a reminder text asking them to take the recall text.

Results

Data from the course exam and recall quiz were analysed to determine the effect of the VR exercises on the participants' knowledge and recall of confined space procedures, dangers and processes. This analysis focused on the descriptive summary of the data and a one-way analysis of variance (ANOVA) to determine if there was statistical significance between the groups. An analysis that compared the course exam means with follow-up quiz means was also used to further develop an understanding of the VR exercises' effects.

During the study period, which lasted approximately 3 months in the summer of 2023, the safety council had 42 372 visitors for training across all sites and online. Of those, 1131 were registered for and assigned to one of the groups for this study. Of these 1131 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 3 days after completing their course. Of the 634 participants who received recall quizzes, 181, or 29%, completed the recall quiz such that (1) 50, or 28% of the participants who responded, had been randomly assigned to the non-VR group, and (2) 131, or 72%, had been randomly assigned to a VR group. Of these participants, 94% were male, which is representative of the learners typically seen at the safety council, and 99% indicated that they were very proficient or proficient in English, which indicates that almost all participants could understand the information presented in the course, in the course exam and in the follow-up quiz. Finally, 97% of the participants indicated that they had no experience or minimal experience with VR in training situations or their personal lives.

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 shown in Table 1.

After 3 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.

The dataset was prepared for analysis by assigning numerical codes to the groups: (1) CBT only course = 1 and (3) CBT with VR course = 2 in SPSS. This coding process allowed for an efficient and structured data analysis. A one-way ANOVA was used to analyse the effects of the treatments on the participants' learning outcomes.

Regarding the research question, this study found no statistically significant difference in knowledge retention for participants who completed the course with VR $F(1179) = 3.56$, $p = 0.061$ and $\eta^2 = 0.019$. The observed effect size indicates that the magnitude of the difference between the averages is not significant. Running Levene's test of equality of variance is used to ensure that the data have met the underlying assumption of homogeneity of variance. When the data from this study were tested against Levene's test of equality of variance in SPSS, the significance value ($p = 0.239$) was greater than the alpha ($\alpha = 0.05$), indicating this data's variance and error variance were equal across all groups, and the underlying assumption of homogeneity of variance was met. There is also no statistical significance for the course exam means, which would show the immediate impact of the VR exercises on the participants $F(1179) = 0.60$, $p = 0.439$ and $\eta^2 = 0.0034$. Levene's test of equality of variance is not significant ($p = 0.209$) and was greater than the alpha ($\alpha = 0.05$), indicating that this data's variance and error variance were equal across all groups, and the underlying assumption of homogeneity of variance was met.

The mean scores on the recall quizzes for participants, however, show that VR provided a better opportunity for memory retrieval ($M = 76.79\%$, $SD = 21.02$) than those who did not have the benefit of VR ($M = 70.40\%$, $SD = 21.47$). When the recall quiz means are compared with the course exam scores that measure the immediate recall, the data show that VR does not provide an immediate benefit but benefits the learner after 3 days. This can be seen in Table 2.

Table 1. Recall quiz descriptive statistics.

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.

Table 2. Means of recall quiz and course exam for VR and non-VR delivery.

Measure	Non-VR		VR		$F(1,179)$	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.

Discussion

Based on the data, the application of short VR exercises within a CBT has the potential to enhance recall 3 days or more after the course completion. Although the results for the participants who took the course augmented with VR compared to the results for participants who did not were not statistically significant, the mean recall quiz scores for participants who took the course with VR exercises were higher than the mean recall quiz scores for participants who took the standard course. Broadly put, this study's research question asked whether differences in knowledge retention exist for participants who took VR courses. The data show that VR exercises offer learners a better chance for transfer of learning.

This can also be found in comparing the course exam means and the follow-up quiz means. Course exams provided immediately after the course show that VR exercises did not immediately impact course exam means. However, means collected on the follow-up recall quiz provided 3 days after course completion yield data showing that VR affected these learners.

Some limitations of this study include that participants were not required to complete the follow-up exam, so a degree of self-selection may have occurred due to this fact. Additionally, only learners with a smartphone could take the follow-up quiz, as the quiz could only be taken with a smartphone. Contractor organisations also have varying degrees of company-specific confined space learning. Within-group learning could have occurred depending on the contractor organisation's training matrix and requirements. This study's random assignment should have ensured that this limitation was kept in check. Finally, the sample was limited to contractor learners who took the safety council's confined space awareness course. Learners who took other courses during the study period were not included.

This study focused on increasing the likelihood of transfer of learning for contractor learners. The fact that participants who took courses with VR exercises performed better on recall quizzes 3 days following the course completion indicates 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 of transfer of learning for contractors when VR exercises and VR exercises with emotionally resonant videos are utilised.

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