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A comparative analysis of video and VR safety training: Usability and Perception

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Abstract **–** Falling from height is considered one of the top causes of workplace injuries and fatalities in the construction industry. The regulatory WAH training, conducted in-class and lecture-based, has been successfully implemented; however, its effect is modest. This study aims to find the relationship between the traditional method and VR simulation in terms of user perception. A crossover design was adopted where participants experienced training in different sequences. Widely used SUS to measure perceived usability and a VR perception questionnaire was implemented. The two-factor analysis of SUS was analyzed. The result shows no significant difference in perceived usability between the training methods. However, on further analysis, one group found video easier to learn. Similarly, there was a significant inclination of users towards VR training in terms of preference, engagement, and ease of remembering. Overall, the user preference for VR interfaces shows that there is a need for further exploration of VR in the current training method.

Keywords**:** Virtual Reality, Working at height training, Usability, Learnability

1. Introduction

It has been reported that falling from height is one of the primary reasons for occupational injuries and fatalities in the construction industry [1]. According to their report, construction sites constitute 38% of the fatalities due to falls in the United States. According to the report by the Ministry of Labour, Training and Skills Development (MLTSD) [2], in 2022 there were 22 fatalities recorded on construction sites in Ontario. Due to the high number of injuries and fatalities, the Ministry of Labor has regulated a mandatory Working-at-height (WAH) training program in 2015 under Ontario's O. Reg. 297/13 [3]. The training is compulsory for the workers working over a hazardous surface, 3 meters in height, or wearing fall protection equipment. Robson et. al. [4] evaluated the effectiveness of the regulatory WAH training program in Ontario between 2012 to 2019. The safety training program was perceived as more useful, gain in knowledge and more confident by the learners. It was concluded that the regulatory training has been adopted widely, and the impact was significant but modest.

Researchers have focused on alternative training mediums to lower the number of reported incidences in the workplace. Burke et al. [5] classified the training into 3 different categories in terms of engagement: Least, Moderate, and Most. The current regulatory WAH training is either lecture or video-based. On the spectrum of engagement, this is amongst the least engaging training methods. The more engaging training methods are causally more effective [5]. Virtual Reality (VR) was the training method on the higher end of the engagement spectrum. VR enhances safety training with an increased level of presence, ability to fail safely, and context-aware training [6]. Furthermore, WAH being considered a high-risk job, VR can create a replication of dangerous and difficult situations keeping workers safe [6].

Employee preference is a major factor in evaluating the effective transfer of health and safety knowledge [7]. Lovreglio et al. [8] created a video and VR simulation of the usage of fire extinguishers. The authors conducted a between-subjects study to evaluate knowledge, self-confidence, recommendation simplicity, and VR user perception. However, trainees in the VR group had to respond to the VR perception questionnaire based on their prior video experience. This experiment does not provide a true comparison of the two training interfaces. Furthermore, Stephan et al. [6] recommended exposing participants to both training interfaces and measuring outcomes after each exposure. Construction workers have limited exposure to VR interfaces, therefore usability and their perception can act as a standard validation tool to accept the interface

[6]. The System Usability Scale (SUS) developed by Brooke [9] was adopted which is widely used to measure perceived usability.

2. Methods

Two instructional mediums were developed: a traditional lecture/presentation format and a virtual environment simulation. The structure and content for these methods were derived from Ontario's official guide for working at height safety and the reference manual from a ministry-approved learning center, ensuring compliance with rules and guidelines. The video presentation contains audio-visual content highlighting workers' rights, the introduction of safety equipment, illustrating hazards, and safe procedures of elimination. Relevant images were used to illustrate the scenarios for the video presentation. The same content was used in the scenarios of VR applications. The iterative interaction design process was adopted to develop VR applications. The 3D model of an under-construction multistorey building, full-body harness, and safety equipment in the format (FBX for unity) was incorporated into the VR environment. Unity was used as a development platform and C# as a programming language. Meta's Oculus Quest 2 was employed as a VR device for the participants.

2.1. Experimental methods

The involvement of human participation required that this experiment be approved by the Laurentian University Research Ethics Board (LU REB). The study adopted a 2x2 crossover experimental design for two reasons: 1) to observe participant's reactions to both training interfaces and 2) to allow participants to compare and evaluate based on their perceptions. The experiment involves the recruitment of 26 students from Laurentian University. Participants were assigned to two groups: Group A and Group B. As shown in Figure 1, Group A also known as the video-VR sequence received video-based training followed by VR, while Group B experienced the reverse order. Inclusion criteria required

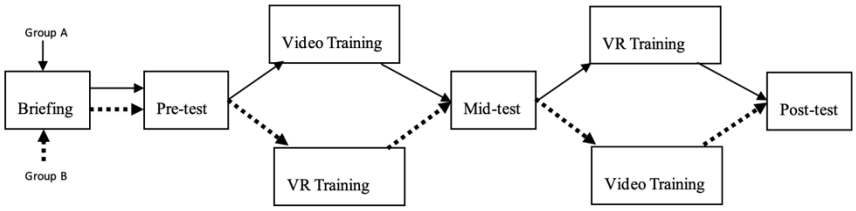

Fig. 1. Experimental procedure

participants to be over 18 years old. Participants with medical conditions like migraines and epilepsy were excluded from the study due to the risk of exposure to VR.

2.2. Procedure

The two treatments, video and VR, were administered in two periods and alternating sequences. Participants were briefed and then randomly assigned to one of two groups: Group A (sequence video-VR) and Group B (sequence VR-video). A pre-test was conducted to record the participant's background. Two tests were performed: a Mid-test after the first treatment and a Post-test after the second treatment. The SUS questionnaire, consisting of a 10-question scale with 5 positive and 5 negative experiences ranging from 1 to 5, was administered in each test. The VR perception questionnaire adopted from Lovreglio et al.'s study was collected in the Post-test. The VR perception questionnaire is a 3 scale-based question ranging from -3 to +3 (strongly disagree - strongly agree).

3. Results/Discussion

The score of SUS was tested using the Shapiro-Wilk normality test ($p < 0.05$). The test confirmed that the distribution of data was not normal. Therefore, a non-normal parametric test, i.e., Mann-Whitney U test, was considered to test

usability scores between two groups in both periods. The score of each question of the SUS for each group and medium can be seen in Table 1. The between-subject study shows non-significant results for most of the questionnaire. However, 'Question 1' in the first period shows a significant difference in score favoring VR training. Similarly, 'Question 4 and Question 10' in the second period have statistically significant differences favoring video.

Table 1. Mean score, standard deviation, and significance of System Usability Scale (SUS) in two periods and two treatment groups. (Stats = Test Statistics (U-value and Z-score), Sig.= Significance at $p<0.05$ and $p<0.01$ denoted by * and ** respectively)

Question	First-period (Group A video vs Group B VR)				Second-period (Group A VR vs Group B video)			
	Video	VR			VR	Video		
	Mean (SD)	Mean (SD)	Stats(U,Z)	Sig.	Mean (SD)	Mean (SD)	Stats(U,Z)	Sig.
Q1	3.54 (0.78)	4.46 (0.66)	33, -2.61	**0.008****	4.08 (1.44)	3.85 (1.07)	61.5, 1.15	0.25
Q2	2.38 (1.04)	1.92 (0.76)	65.5, 0.94	0.34	2.31 (1.03)	1.69 (0.48)	55.5, 1.46	0.14
Q3	3.46 (0.97)	4.08 (0.64)	55.5, -1.46	0.14	4.00 (1.00)	4.15 (0.80)	80, -0.20	0.83
Q4	2.54 (1.61)	2.54 (1.13)	79, -0.25	0.79	2.85 (1.21)	1.23 (0.44)	22, 3.18	**0.001****
Q5	3.46 (1.05)	3.92 (0.64)	62, -1.13	0.26	3.92 (1.04)	3.77 (1.01)	76, 0.41	0.68
Q6	2.38 (1.04)	2.38 (0.77)	78.5, -0.28	0.78	2.15 (1.21)	1.77 (1.01)	67.5, 0.84	0.39
Q7	3.31 (1.44)	4.38 (0.51)	47.5, -1.87	0.06	4.15 (0.69)	4.31 (0.75)	73.5, -0.54	0.60
Q8	2.54 (1.33)	2 (0.82)	67.5, 0.84	0.39	2.31 (1.03)	2.08 (1.32)	69.5, 0.74	0.46
Q9	3.62 (1.12)	4 (0.41)	71, -0.67	0.50	4.15 (0.99)	4.08 (1.04)	80, 0.21	0.83
Q10	2.92 (1.75)	1.84 (0.69)	58, 1.33	0.18	2.46 (1.27)	1.31 (0.48)	35.5, 2.49	**0.01***

The unidimensional score of SUS was calculated using Brooke's original method. The mean overall SUS score for Group A was: 61.54 for Video and 70.58 for VR. Similarly, the mean overall SUS score for Group B was: 75.38 for VR and 80.19 for video. Both between-subject and within-subject study on overall SUS score shows non-significant differences. The decomposition of the SUS score into two components: "Usability" and "Learnability" was developed by Sauro and Lewis [10]. The "Learnability" factor contains the original questions "4 and 10" while "Usability" is composed of the remaining 8 questionnaires. Further analysis was conducted on two key factors: usability and learnability. The between-subject study conducted in the first and second periods revealed no significant differences. Similarly, there was no significant difference in the within-subject score of Group A. However, there was a significant difference in the within-subject score of Group B, which suggests the participants found it easier to learn with video training.

Table 2. The number of participants and their ranking in the VR perception questionnaire from Strongly disagree to Strongly agree. (-3 = Strongly disagree, -2 = Disagree, -1, Somewhat disagree, 0 = Neutral, 1 = Somewhat agree, 2 = Agree, 3 = Strongly agree)

Questions	-3	-2	-1	0	1	2	3
I found VR simulation more engaging than lecture-based training	0	1	0	2	4	8	11
It was easier to remember fall protection recommendations provided in VR simulation than those provided in lecture-based training	-4	0	0	4	4	8	6
I prefer the VR simulation over lecture-based training	-4	1	0	4	3	4	10

The perception questionnaire was based on the overall experience of participants in terms of engagement, ease of remembering, and preference which is illustrated in Table. 2. The VR perception questionnaire reveals participants' preferences and attitudes towards the VR training experience in all three aspects. The result of the VR perception questionnaire is consistent with the findings of Loreglio et al.'s study [8]. This study overcomes the limitation of their evaluation of VR perception by implementing the crossover design. The SUS score indicates no significant difference in

perceived usability between the two training interfaces. Additionally, factor analysis revealed that the VR system was more difficult to learn for the group that experienced VR first, followed by the video.

4. Conclusion

The primary aim of this study was to compare VR with traditional training methods in terms of trainee's perceptions. The results indicate no significant difference in usability; however, participants may find learning in VR challenging. The interface of future VR applications should be easier to operate. Despite this, most participants agreed that VR provides a better learning experience, with increased engagement and easier retention of information. Crossover design has been applied to assess both between-subject and within-subject studies. This design can be further explored to study how VR can be integrated into the current training method to find an optimal sequence. In addition, objective measures to analyze learning, skills, and behavior should also be blended to study the comprehensive effectiveness of the training medium. A significant limitation of this study is the lack of actual workers as participants, which may have resulted in bias. Future studies should explore this design approach in actual trainees' performance using both subjective and objective measures.

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