Development of Virtual Reality Simulation for Emergency Evacuation in Education

Ulan Dakeev, Reg Pecen, Faruk Yildiz and Luong Y

Sam Houston State University, Texas.

Abstract

Virtual Reality has recently developed as a prevalent technique adopting in numerous fields of scientific experiments. The thriving concept of simulating an interaction environment broadens the researchers' competence to design the ideal virtual experimental conditions and manipulate the environment's layouts sufficiently. The idea of practicing an emergency evacuation by a computer simulating model that reflects the physical environment analogously has been taken into account. This study aims to investigate whether the Virtual Reality simulation could be an optimal method for the emergency evacuation training, especially in the educational environment. Fifteen volunteers with no familiarity with the environment structure participated in this study, and experiments were plotted in two environments – the well-defined virtual environment for pretraining and the original physical environment for practical situation. The main hypothesis predicts that VR can effectively shorten the amount of time that pre-trained users spend to locate the emergency exits of a specific floor plan.

Keywords: virtual reality, emergency exits, safety training.

Introduction

Emergency situations are those that may lead to serious property damage, life-threatening and serious impacts on environment, which may be listed as fire, flood, explosion hazard, etc. An emergency situation that is not quickly controlled can develop into unpredictable catastrophic circumstances such as injuries and property damages. Harvey Hurricane in Texas in 2017 illustrates this point clearly. When Harvey made its landfall in Texas the beginning of August 2017, it became the country's first major hurricane as a Category 4 hurricane striking southern Texas since the Celia in 1970. Harvey ranks the second in the total damage by $125 billion. Regarding Harris County, heavy flooding forced 39,000 people evacuating. 36 storm-related deaths are recorded as of September 27th, 2019. Thus, a well-organized emergency evacuation is the prominent procedure. In recent years, researchers have investigated a variety of approaches to prepare for emergency evacuation. One of the potential techniques aiding the evacuation researches effectively is Virtual Reality technique.

The past decade has experienced the rapid development of Virtual Reality. Virtual Reality is a phenomenon describing the computer simulated environment. As Virtual Reality simulation has been developed vigorously since the beginning of 20th century, it has been utilized for nonentertainment purposes. Virtual Reality has played an important role in various scientific and industrial processes. Smith et. al. (2015) conducted a study which supports the benefits of using VR simulation as a supplemental teaching strategy, particularly in nursing. In addition, ZIO et. al. (2019) also demonstrates that VR is an effective approach supporting civil aviation in the training of aircraft maintenance. In addition to that, Zhang et. al. (2017) proved that VR technology is a promising method that is suitable for mine safety training.

Besides applying VR in nursing school as well as aviation education, researchers have applied the Virtual Reality in emergency evacuation study and fire extinguishment practice. Considering fire extinguishment training, the majority of live simulations in training was formerly building a live physical environment. Trainees, such as firefighters, gained the spatial knowledge acquisition through the process of experiencing real-life training. However, live simulations may be impractical and not sufficient due to the requisite amount of time and resources. As a result, the application of Virtual Reality as a simulator in training for emergency evacuation is on the growth. Moreover, the implementation of virtual environment will improve users' spatial cognition in a safe, repeatable, controllable and measurable way. For this reason, diverse experiments have been held to examine how VR influences on the way people find their way out of the emergency scenarios. Tang et. al. (2009) has used Virtual Reality as a tool to construct an experimental space to determine how emergency signs expedite way-finding. In his research, three-scenario emergency escape game has been set up with the participation of 107 subjects to determine how emergency signs facilitate human way-finding process. Vilar et. al. (2013) conducted their experiment on the influence of physical environmental features such as brightness and intersections accentuate on pathway-finding in an emergency using VR-based methodology. Çakiroğlu and Gökoğlu (2019) investigated the transferability of the behaviors and skills acquired in Virtual Reality environment to real-life condition. The experiment designed a game-based simulator by setting up a fire safety training with the participation of 10 children. Tucker et. al. (2018) designed a pilot study with the evacuation scenarios where there are various actual movement avatars so the experimental subjects can participate with highly realistic and immersive evacuation simulation.

Literature Review

As Virtual Reality has become a sufficient approach for the training procedure, researchers such as Bliss and Tidwell (1997) involved VR as a promising training method for firefighters and ascertained that VR training allows participants easily to attain the configurational knowledge. In particular, recent advances in Virtual Reality techniques have facilitated the investigation of human way-finding in general. Regarding emergency evacuation training, researchers such as Çakiroğlu and Gökoğlu (2019) and Tucker (2018) have utilized Virtual Reality as the experimental approach. Virtual Reality, after all, has become a supportive manner to create the simulacrum for the emergency situation, by which the spatial knowledge acquisition becomes more participatory.

While many types of research have been carried out by the assistance of VR, the difference between the way-finding time in VR-environment and physical environment has not been closely examined. Most of the initial studies and observations have so far built on the circumstance where the disaster is striking, and experimental subjects encounter ongoing emergency scenarios such as fire or hazardous explosion. In the study of Vilar et. al (2013), all participants remained standing during the experimental session at the same location. Çakiroğlu and Gökoğlu's experiments (2019) are set up a similar method where the participants staying at the same place sing joystick to endure the emergency scenario. While both types of research are carried out with different purposes, the methodology was remaining the same and the participants did not have the opportunity to endure the physical environment where they experience in a Virtual Reality environment. In Tucker's experiments (2018), although participants adapted the real physical environment of the fixture of the emergency scenario, most of them were familiar with the experimental fixture. Furthermore, the scenario with signs of smoke and other avatars can have effects on how participants navigate the emergency exits. One more obstacle that most of the initial study encountering is the sample

variation. While some of them are children, the others are adults who are familiar with the experimental fixture, which has a significant effect on how they locate the nearest emergency exit.

By employing the VR techniques integrated with the three-dimensional floor plan of the Fred Pirkle Building of Sam Houston State University, this project aims to analyze the disparity of time used to locate the nearest emergency exit within VR environment versus actual physical configuration by participants – who have no prior spatial cognition about the experimental environment.

Methodology

This project investigates the effectiveness of VR tool in aiding people with no prior spatial cognition to locate emergency exits in the Fred Pirkle Building of Engineering and Technology at Sam Houston State University.

The researchers developed the floor plan by using Autodesk Revit as Figure 1, entailed the images capturing the real physical environment. Researchers ensured that the virtual environment is as much analogous and realistic as the physical environment. The floor plan thenceforth is generated into a three-dimensional environment to be capable for Virtual Reality tools by the aid of SimLab Composer – a product of Unreal Engine.

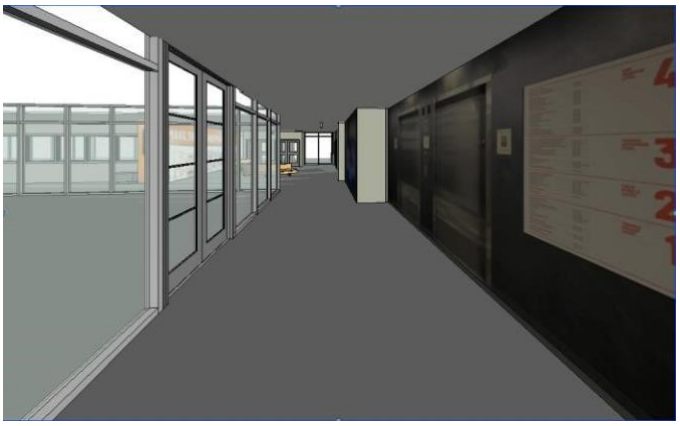

Figure 1. Simulation setup. Examples of the virtual experimental environment – inside of Fred Pirkle Building of Engineering & Technology at Sam Houston State University developed by Autodesk Revit.

Oculus Rift S by Oculus VR was used as the reality simulation for this experiment. Participants used the set of controllers connected with the Oculus Rift S to teleport in the simulated environment as in Figure 3 and 4.

Figure 2. Participant experience the fixture by the VR tools in SimLab Viewer.

Figure 3. Participant experience the fixture by VR tools in SimLab Viewer.

A total of 15 students from diverse colleges, such as Criminal Justice and Health Science, at Sam Houston State University who have no familiarity with the floor plan and have never experienced the fixture inside the building, with diverse socio-ethnic background, participated in the study. Participants were provided the consent forms to inform their awareness and acceptance of the experimental procedure. No physical and mental condition was reported that prevented them from participating this case study. Participants were divided into two groups: the conventional with the total 8 participants and the experimental group with the total of 7 participants as shown on Figure 4. Researchers titled the standard and experimental group “With VR Experience” and “Without VR Experience” groups respectively.

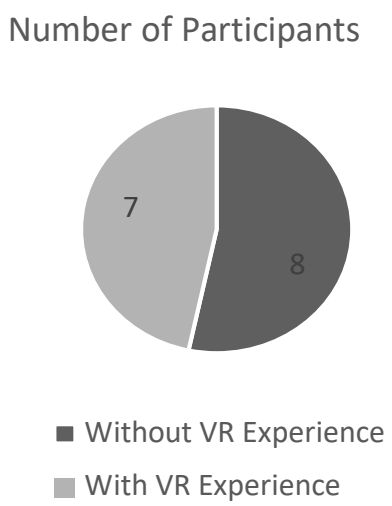

Figure 4. Distribution of No VR Exits and With VR Exits groups

The "Without VR Experience" group (the standard group) explored the second floor of the Fred Pirkle Building starting from the elevator. The time is re corded from when the participants departed from the elevator door till when they could eventually approach the total of three exits. On the other hand, the "With VR Experience" group (the experimental group) firstly toured the completed three-dimension building fixture via the Virtual Reality tool. Similarly, participants in the experimental group accessed the floor and located three exits in the fixture from the elevator door which is the same starting point as of the conventional group. After that, they were set up to explore the physical environment following their initial VR experience. Correspondingly, the time that participants spent to approach the total of three exits is recorded. No guidance is provided except ceiling-mounted exit signs.

The time that two groups occupied to approach the emergency exits was statistically analyzed to interpret the significance of the VR tool in the way-finding process.

Data Analysis

Researchers conducted an independent sample t-Test on the time of 15 participants used to find the exits in experiment. The Table 1 illustrates the mean value of time for the experimental group "With VR Experience" is 15.489 seconds less than the value of time for the standard group "Without VR Experience."

Group Statistics

Group		N	Mean	Std. Deviation	Std. Error Mean
Time	Without VR Experience	8	72.068	15.398	5.444
	With VR Experience	7	56.579	5.135	1.941

Table 1. Resulting Statistics for Participating Groups

Moreover, the independent sample T-Test (Table 2) run with SPSS illustrated that the p-value of the test is approximately $0.03 < p=0.05$ which is significant. By other words, this statistically significant difference provides support for the hypothesis that VR can effectively shorten the amount of time that pre-trained users spend to locate the emergency exits.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Time	Equal variances assumed	8.377	0.013	2.531	13	0.025	15.489	6.120	2.267	28.710
	Equal variances not assumed			2.680	8.728	0.026	15.489	5.780	2.352	28.625

Table 2. Independent Sample t-Test Analysis for the No VR Exits and With VR Exits Groups

Overall, the researchers received positive feedbacks on the effective of Virtual Reality in improving pathway finding from participants. In other words, Virtual Reality technique could be an effective way for safety training, especially for pre-training for emergency evacuation. Although Virtual Reality technique literacy may be a hindrance to people especially those who have little to no experience with this technology, the Virtual Reality tools could benefit human beings in safety and pathway finding in emergency situations.

Summary and Conclusion

This research provides evidence for the potential capability of Virtual Reality technique in preparing the training for evacuation in emergency situation. An immersive virtual environment could be used as an effective pre-training tool for evacuees, especially in educational buildings similar to this study case. According to the accomplished result, there is a significant difference in the mean value of time two groups of participants used to locate emergency exits – the amount of time the experimental group with Virtual Reality pre-training used is significantly shorter than the amount of time used by the standard group. As presented in the statistical analysis, there is sufficient evidence within 95% confidence interval to conclude that Virtual Reality pre-training

process can shorten the time people use to locate emergency exits in a specific floor plan. This result proves that Virtual Reality could become a potential technological method for emergency preparedness. Notwithstanding, the research also captured the obstacles in the Virtual Reality equipment operation for a small number of participants as they have little to no experience with any of Virtual Reality technique. Thus, training to improve Virtual Reality technological literacy is recommended to enhance the users' capability in such circumstance. Furthermore, the virtual is required to be realistic and immersive in order to create the sense of presence for the participants. Overall, The Virtual Reality tools can be a potential technological method to subsidize the traditional pre-evacuation preparedness and emergency safety training.

Future Works

Virtual Reality tools and its associated devices have captivated human beings' interest to explore and broaden their capability in recent decades. Future researches should be conducted with a specific immersive and realistic virtual situation, such as active shooters, in order to access to how emergency pre-training with virtual environment benefits users.

References

Bliss, J. P., Tidwell, P. D., & Guest, M. A. (1997). The Effectiveness of Virtual Reality for Administering Spatial Navigation Training to Firefighters. Presence: Teleoperators and Virtual Environments, 6(1), 73–86. https://doi.org/10.1162/pres.1997.6.1.73

Çakiroğlu, Ü., & Gökoğlu, S. (2019). Development of fire safety behavioral skills via virtual reality. Computers & Education, 133, 56–68. https://doi.org/10.1016/j.compedu.2019.01.014

Smith, P. C., & Hamilton, B. K. (2015). The Effects of Virtual Reality Simulation as a Teaching Strategy for Skills Preparation in Nursing Students. Clinical Simulation in Nursing, 11(1), 52–58. https://doi.org/10.1016/j.ecns.2014.10.001

Tang, C.-H., Wu, W.-T., & Lin, C.-Y. (2009). Using virtual reality to determine how emergency signs facilitate way-finding. Applied Ergonomics, 40(4), 722–730. https://doi.org/10.1016/j.apergo.2008.06.009

Tucker, A., Marsh, K. L., Gifford, T., Lu, X., Luh, P. B., & Astur, R. S. (2018). The effects of information and hazard on evacuee behavior in virtual reality. Fire Safety Journal, 99, 1–11. https://doi.org/10.1016/j.firesaf.2018.04.011

Vilar, E., Rebelo, F., Noriega, P., Teles, J., & Mayhorn, C. (2013). The influence of environmental features on route selection in an emergency situation. Applied Ergonomics, 44(4), 618–627. https://doi.org/10.1016/j.apergo.2012.12.002

Zhang, H. (2017). Head-mounted display-based intuitive virtual reality training system for the mining industry. International Journal of Mining Science and Technology, 27(4), 717–722. https://doi.org/10.1016/j.ijmst.2017.05.005

ZIO, E., FAN, M., ZENG, Z., & KANG, R. (2019). Application of reliability technologies in civil aviation: Lessons learnt and perspectives. Chinese Journal of Aeronautics, 32(1), 143–158. https://doi.org/10.1016/j.cja.2018.05.014