Chapter 67
Virtual Reality-Based Fire Safety Training for the Indian Context

Alan Sha, Anmol Srivastava, Madhav Haldia, Pranav Kumar, and Pankaj Badoni

Abstract A large number of fire accidents occur across India every year due to appalling status of fire safety measures and general laxity among the public. This paper explores the potential of virtual reality (VR) to educate and raise awareness amongst the masses about precautionary measures of fire safety. The VR experience is primarily targeted for non-fire fighters. A user-centered design approach was adopted to identify various problems faced at the time of fire emergencies. Semi-structured interviews were conducted, and online surveys were utilized for data collection. Based on insights gained from analyzing the collated data, VR experiences were prototyped utilizing Google cardboard and HTC vive. The prototypes educate the user about the use of fire extinguishers and behavior of smoke.

67.1 Introduction

Fire is a major disaster that threatens human safety. In India, houses and institutions are prone to fire due to lack of safety knowledge and the absence of emergency measures. According to a published report by the National Crime Records Bureau (NCRB) [1], thirty-five ($n = 35$) Indians die in a fire incident daily. Of the fire fatalities reported in 2018, 4290 were in age group of 18–30, and 3860 were in age group of 30–45. These numbers show the severity of the problem and lack of knowledge of Indian masses about fire and safety. These alarming numbers also emphasize that the educational institutions and industries must attach great importance to fire safety training. In addition, the onus also falls on the general public to learn and master the fire safety measures and necessary skills to prevent the fire and handle it properly in case of fire accidents. Fire safety education is a combination of knowledge learning and operational exercise, where teaching method plays a vital role. Until now, traditional teaching methods primarily relying on textbooks and multimedia presentations have been utilized. However, these methods are unable to capture the

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essence of a hazardous environment and lack the experiential component. With the emergence of virtual reality (VR) technology, realistic three-dimensional (3D) virtual environment and immersive multi-sensorial experiences can be designed. Owing to these capabilities, VR has been utilized for many training and educational purposes. VR has also been explored extensively for fire safety training [2–4]. However, how can this technology be utilized for educating the masses especially in an Indian context? To address this question, this study adopts a user-centered design (UCD) methodology to identify the problem and design suitable solution. The aim was to understand the main problems faced in fire safety situations in Indian context through the eyes of both fire fighters and non-fire fighters. For this, qualitative data collection techniques such as semi-structured interviews and field observations were utilized. Based on the insights gained from the analysis of data and through the literature reviews, VR fire safety training experiences have been prototyped.

67.2 Literature Review

Fires are classified by the kind of fuel involved. Not all extinguishing agents are good with a wide range of fuel (e.g., water utilized on a flammable fire is probably going to build the pace of burning significantly and to scatter the fuel to cover a greater area). Thus, if a wrong fire extinguisher is chosen, the fire circumstance can be made worse, often your own personal safety. A few fire extinguishers are just more effective than others on specific classes of fire. Various classification of fire has been provided in the literature [5]. Most fire extinguishers have a pictograph label identifying the type of fuels that may be extinguished. An understanding of basic principles of combustion or fire, causes and sources of ignition, fire growth and fire spread are necessary for understanding the principles of fire control and extinguishment. Combustion usually requires an exothermic chemical reaction between a substance or fuel and oxygen. Unlike slow oxidation, a combustion reaction occurs so quickly the heat is generated faster than it is dissipated, causing a marked increase in temperature, even up to a few hundreds of degrees. Frequently, the temperature reaches so high that visible light or flame is generated. It has been shown from the triangle of fire that three factors are essential for combustion (refer Fig. 67.1). An interesting protocol to teach about fire safety is the PASS protocol. Pull the pin, aim the extinguisher nozzle at the base of flames…squeeze trigger and sweep the extinguisher or nozzle from side to side covering base of the fire [5].

A number of studies [2, 3, 6, 7] have been published on fire safety training in VR which primarily focus of fire simulation, fire safety training, smoke behavior, fire and safety in VR. Among them, Kobes and Helsloot [2] researched on the possibilities of virtual reality for studying human behavior in fires are so far scarcely adopted by researchers. The application of a behavioral assessment and research tool (BART) in virtual reality is expected to be an important addition on the existing research methods. Shamsudin [3] reviewed the history, attributes, and application of virtual reality in training and education for construction safety and health course. While

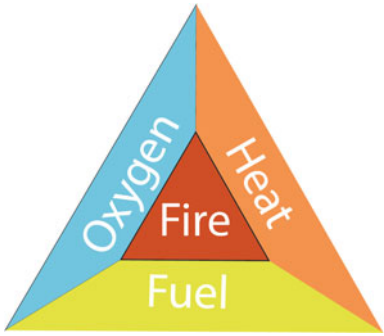

Fig. 67.1 Fire triangle

doing fire safety training in real environment, Eglin et al. [4] stated that the longer duration of exposure coupled with the inability to dissipate heat whilst wearing protective clothing can result in considerable physiological strain for fire fighter instructors [10]. Williams-Bell et al. [11] stated that the colleges and universities must attach great importance to fire safety education. Each student must learn and master the fire safety knowledge and necessary skills to prevent the fire and handle properly in the event of fire [11]. Feng and Xiao [6] suggested that a VR fire drill system has a practical significance and is instrumental in fire drills, fire safety training, and other applications [12]. Bernardes et al. [7] established virtual reality that can be a valuable tool for fire safety training, as the training can be more effective, VR reduces cost, and can increase the safety of individuals [13]. Fanfarová and Mariš [8] presented the possibility of using modern simulation tools using computer softwares. The study suggests training in VR that improve and increase the level of preparedness of fire and rescue services [3]. Yu and Guan [9] suggested that virtual training methods should be used for fighters for better performance [14]. Martínez [15]. The lack of interactivity and high equipment complexity also leads to the low practicability [15]. Moreno et al. [10] have discussed various simulations dealing with fire extinguishment actions, natural and artificial fire breaks, and various wind conditions. [16]. The authors used different fire propagation algorithms. Yang et al. [13] apply VR for gas explosion training [18]. Wang et al. [14], the paper establishes applications of fire disaster simulation and virtual fire training by using collaborative virtual geographic environment (CVGE) platform—CySim, which is developed based on open source open simulator server and second life client. García-Hernández [16], for in emergency situations, the tools described in this paper like 3D images 360° images for fighters were preferred to the already existent self-protection plans [11]. Xi and Smith [17] the success of using professional numerical fire simulation tool to support non-player characters behavior in virtual environment will provide a new way to enhance the realism of virtual environment by using high fidelity fire data sources [15]. Shamsudin et al. [3] state that VR training environment can provide a diversity of equipment operation scenarios for teaching and learning [9]. Zhang et al. [12] established that VR has enriched the teaching form of fire safety education on campus, which can effectively help students learn fire safety knowledge,

master fire safety skills, and improve fire safety education effect [17]. Viant et al. [20] fire safety education emphasizes the close combination of knowledge learning and operational practice. It is important to choose the appropriate teaching method [20]. Houvouras et al. [21] fire drills can effectively help students become familiar with firefighting equipment and learn extinguishing and self-protection skills [21]. Querrec and Chevaillier et al. [22] proposed a storytelling-based approach to VR fire training [22]. Xu a et al. [18]. Rena visualization technique based on volume rendering and fire dynamics data has been especially designed to create a realistic and accurate smoke environment for the purposes of effective virtual training, which allows the trainees to experience a realistic and yet non-threatening fire scenario[7]. Itamiya et al. [19] used AR system for an experiment in evacuation drills natural hazards in elementary schools and virtual reality; it was very useful improving crisis awareness of students [20].

Based on the literature review, several directions for research in fire safety training have been identified. As the main aim of this research is to utilize VR for training the general public, which needs to have better reach in terms of equipment accessibility and cost, PASS protocol was chosen to be implemented for Google cardboard.

67.3 Methodology

This study utilizes a UCD approach and employs various design methodologies to identify the crucial needs. Semi-structured interview, field and online surveys were utilized for data collection.

67.3.1 User Interviews

The primary objective of the user interviews was to understand the problems which are faced in firefighting from the perspective of both firefighters and non-fire fighters. Semi structured interviews were conducted among ($N = 10$) participants.

Table 67.1 depicts the type of participants interviewed (Age group: 20–45, Male).

Table 67.1 List of participants and number of participants

Participants	Number of participants (10)
Fire safety manager	1
Fire fighters	2
Fire safety students	4
Fire safety instructor	1
Non-fire fighters	2

Fig. 67.2 Affinity analysis diagram from user interviews conducted

Questions pertaining to participants' work experiences and knowledge about fire training were asked. User diaries and audio recordings were utilized to document and capture interviews. The audio recordings were later transcribed for affinity analysis. Questions were asked based on the experiences of the participants regarding the real-life experiences regarding fire. Problems they faced while when fire accidents happened, what kind of training would help them in fighting fire and most common fire situations (Fig. 67.2).

From the affinity analysis, it was understood that PASS protocol is the most important protocol that should be trained for the non-fire fighters among all the other fire extinguishing techniques.

67.3.2 Surveys

An online survey was conducted to understand the knowledge and behavior about fire and safety. The study recruited participants in which 71.4% were male and 28.6% were female. 90.5% of the participants were in the age group 21–30. Around 57.1% were students, and 28.6% of them are employees; 14.3% are either students or employees related to fire and safety (Table 67.2).

Around 58% of the participants are not sure about the exact sound of the fire alarm. When the fire alarm is activated, 61.9% candidates feel panicked. The survey reveals that participants not associated with fire safety training lack basic understanding about fire safety and its relevant aspects—which is a cause of concern. It was also identified that these participants are also unaware of using fire extinguishers. The insights gained form user research and the literature reviews were then converted

Table 67.2 List of yes or no questions asked in the online questionnaire

Questions	Yes (%)	No (%)
Do you have any kind of previous fire safety training experience in your job or institution?	60.3	39.7
Everyone should know do's and don'ts in case of fire emergency	100	0
Everyone should be trained in fire prevention control	92.1	1.6
Do you know about fire triangle and its components?	34.9	65.1
Do you know about different types of fires?	46	54
Do you know about different types of fire extinguishers?	42.9	57.1
Do you know about "PASS" method of fire control?	22.8	22.2

Fig. 67.3 Scenario used for making fire extinguisher training

into information architecture and working prototypes. Storyboarding technique, refer Fig. 67.3, was adopted to envision how fire-extinguisher training module can be presented as a part of an immersive user experience.

67.3.3 Basic Fire Safety Training Using Fire Extinguisher

Methodology given in (Fig. 67.4) shows how a prototype for Google cardboard has been made for training non-firefighters in PASS protocol.

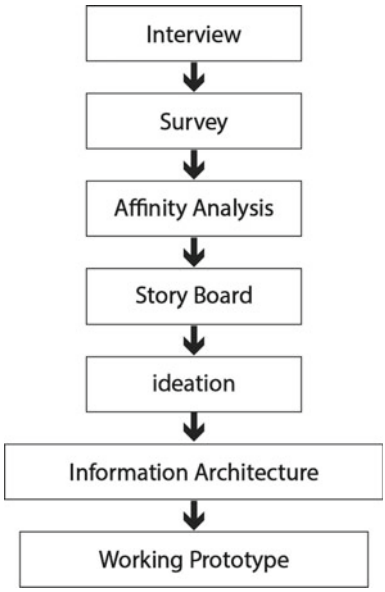

Fig. 67.4 Methodology used in making a working prototype for fire extinguisher training in Google cardboard

67.4 Ideation

In ideation part, the PASS protocol for VR fire extinguisher training is laid out stepwise (Fig. 67.5).

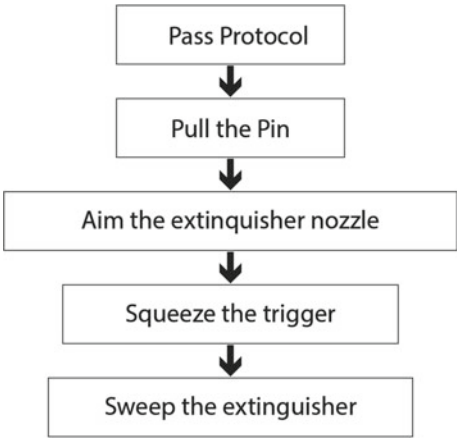

Fig. 67.5 Steps followed in PASS. protocol

67.4.1 Information Architecture

Insights from user research led to the formulation of information architecture for basic training scenarios in case of using fire extinguishers, kitchen fire accidents, fire evacuation using fire exits, and also how to react to different types of fire (Fig. 67.6).

Unity is the ultimate game development platform. Unity can be used to build high-quality 3D and 2D games, deploy them across mobile, desktop, VR/AR, and console. It is a cross-platform game engine. Which is primarily used to develop video games and simulations for computers, consoles, and mobile devices. Objects and models for the environment were made using Blender 2.80, SketchUp 2019. The interactive prototype was made for Google cardboard. Gaze-based interaction has been used to interact with different objects in the prototype since it does not need any extra gadget than the mobile device (Fig. 67.7).

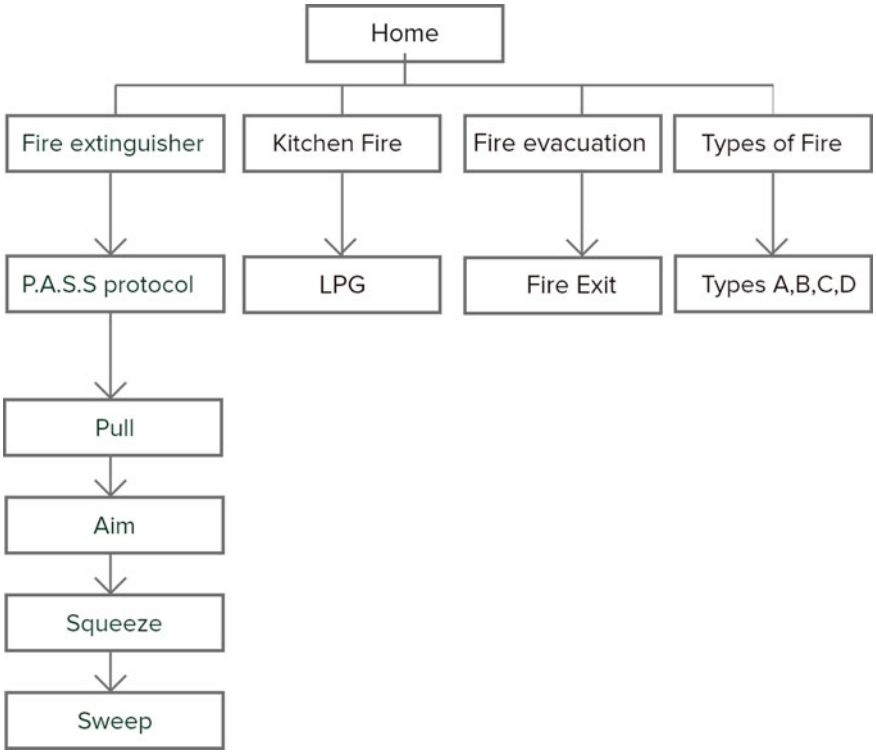

Fig. 67.6 Interaction map for VR training in fire extinguisher training

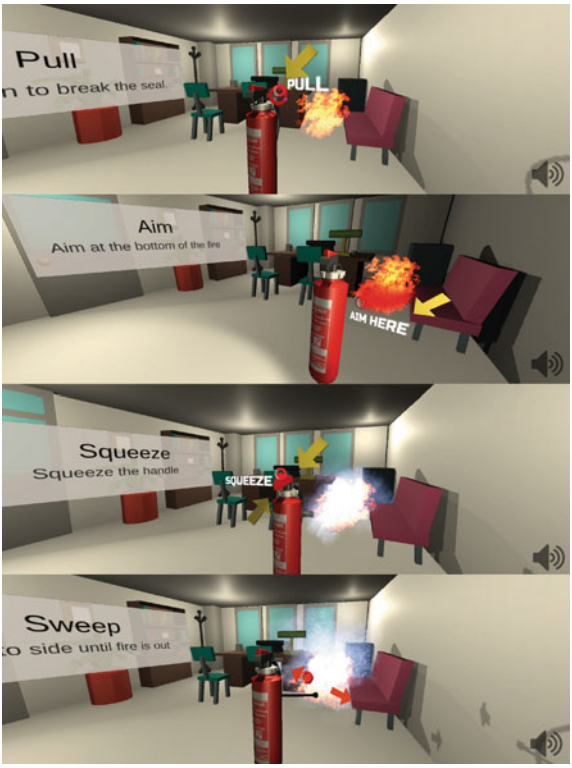

Fig. 67.7 Prototype "PASS" protocol for Google cardboard

67.5 Discussion

From the study, it is understood that there is a research gap for training of non-fire fighters in virtual reality in Indian context. Using low-cost VR headsets like Google cardboard can be solution for making masses understand the basics of fire safety training so that they can have clear understanding of different methods of fire extinguishing. Since there are limited input devices in Google cardboard, alternative input methods have to be used. Due to the COVID-19 lockdown situation of 2020, no further usability test was conducted to show how VR helps in fire training more than the existing training methods. Usability tests needs to be conducted in future so that it could be proven with help of data whether using this as a training method in Indian context is useful or not. By giving a voice interface and using commands to guide can make the prototype immersive and more functional.

67.6 Future Work

67.6.1 Fire Safety Training for HTC Vive

A virtual simulation for fire safety training in smoke chamber was developed using unreal engine for HTC vive. The smoke behavior and simulation are made similar to real-life scenarios. Smoke chamber is a common type of fire safety training given to fire fighters (Figs. 67.8 and 67.9).

Using this prototype is not practical for training non-fighters since the gadget needed for this is HTC vive. HTC vive is expensive and not easy to access in an Indian context.

Fig. 67.8 Smoke chamber simulation for HTC vive

Fig. 67.9 VR environment and smoke behavior in smoke chamber simulation for HTC vive

67.7 Conclusion

Fire safety education is important for both students and professionals. This study shows how low-cost methods like Google cardboard can be used as a method of training for non-fire fighters. Fire safety training can be further developed using VR effectively and more immersive. For Indian masses under the current situation, these types of training methods will be more time saving, and it gives better safety than exposing to real fire environment.

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