Development of a Virtual Reality Serious Game for Fire safety training

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Abstract

Fire safety is a critical concern in society, and there is a need to develop effective training methods to educate people on how to respond to fire emergencies. Virtual reality (VR) has been increasingly used in training scenarios due to its ability to simulate real-life situations. The objectives of this study were to develop a fire safety training simulation game by using VR technology, which provide an immersive experience that allowed players to practice fire safety responses in a simulated environment, for both entertainment and training purposes, and to evaluate the quality of the game in terms of fire safety training. The game was developed not only for entertainment purposes but also to provide fire safety training knowledge. Its development process involved designing a scenario of a burning building, creating game mechanics, and developing the game using the Unity engine. For its assessment, first, three professional firefighters evaluated the game's quality using a qualitative evaluation form. The expert comment indicated that the game was well-designed, well-structured, and good enough to use for fire safety training and entertainment purposes. Second, the game was performed by 20 of 18-30-year-old individuals, as a player, for evaluating their knowledge of how to survive a fire in a burning building. The comparison between the knowledge score before and after playing the game effectively demonstrated the improved knowledge of how to survive a fire in a burning building. Future studies should examine the game's effectiveness when combing with the on-site training in enhancing people's knowledge and skills related to fire safety.

Keywords: *Virtual Reality, Fire safety training, Simulation game*

1. Introduction

In recent years, simulation games are being used as an alternative media for educating various skills, practicing critical thinking processes, or even being used as training tools for many purposes. This kind of game will provide players with scenarios that reflect the real world. Players have to take a roleplay and make a decision on given options so that they can test the outcomes of their actions leading to a more engaging learning experience compared to other forms of media. Not only used for entertainment but also the simulation game can be used to create some serious and dangerous situations to let the players practice how to confront and deal with them, promoting survival skills and problem-solving skills to make them ready when they encounter in their real-life [1]. To make the simulation game to be more effective, Virtual Reality (VR) technology is also applied to make players experience more realistic situations [2].

According to the Department of Disaster Prevention and Mitigation of Thailand, even though the incidents of fires seem to be under control, the increasing damage value is surprisingly reported [3]. These statistics demonstrate that fire accidents are one of the significant causes of injuries and deaths in Thailand. In some cases, the cause of these losses is due to the lack of knowledge, understanding, and training in dealing with fires, which leads to anxiety and an inability to deal with the actual situations safely when confronted with them. As a prevention, the importance of preparedness for fire should be first concerned. This can provide an opportunity to be able to survive and improve

decision-making skills [4]. Moreover, learning how to use fire-preventing equipment and understanding the practical procedures should be included in the lesson on preparedness for fire safety training.

As mentioned above, many media have been used as supporting learning tools. This leads us to be interested in the development of a serious game for fire safety training to make the lesson become more interesting while combining it with VR technology to provide the players a high immersion through virtualization giving a realistic experience to enhance their learning effectiveness with any harmless. In this work, We developed a VR serious game for fire safety training by focusing on basic practical procedure training, for example; identifying escape routes for fire exit, how to use the fire extinguisher, etc. This purpose is to promote the surviving skills, problem-solving skills, and the ability to analyze and prioritize steps for individuals aged 18-30 years in a critical situation like a fire. Through practical training for fire safety training by using our VR serious game, players will gain understanding and familiarity with survival strategies when facing real disaster situations.

2. Methods

This section provides detailed information about our designs for this VR serious game for fire safety training, the instruments we used to develop the game, how to evaluate the quality of this VR serious game, and how to assess the knowledge achievement test after playing the game.

2.1 Game design and process

To design this simulation game, we set the goal that this game will give the players fire safety training through VR technology with the provided game missions (for example, how to escape from fire by using provided tools, how to extinguish fire correctly by using the correct type of fire extinguisher, etc.). After collecting the necessary information and useful knowledge related to surviving fire, we designed the game features and developed them by using the following software as a tool for the simulation game; the Unity engine, a game engine for developing the 3D simulation game for VR devices, and the Autodesk Maya, a 3D modeling, animation, and rendering software for creating 3D models, textures, and animations, in this VR game. The C# programming language was also used in the game development. And in the final process, it was also evaluated for its quality and how much the players gained their knowledge after playing the game. The game stages are divided into 3 modes; which are the tutorial mode for basic fire training, the fire survival training mode, and the indoor fire survival mode, as shown in Figure 1.
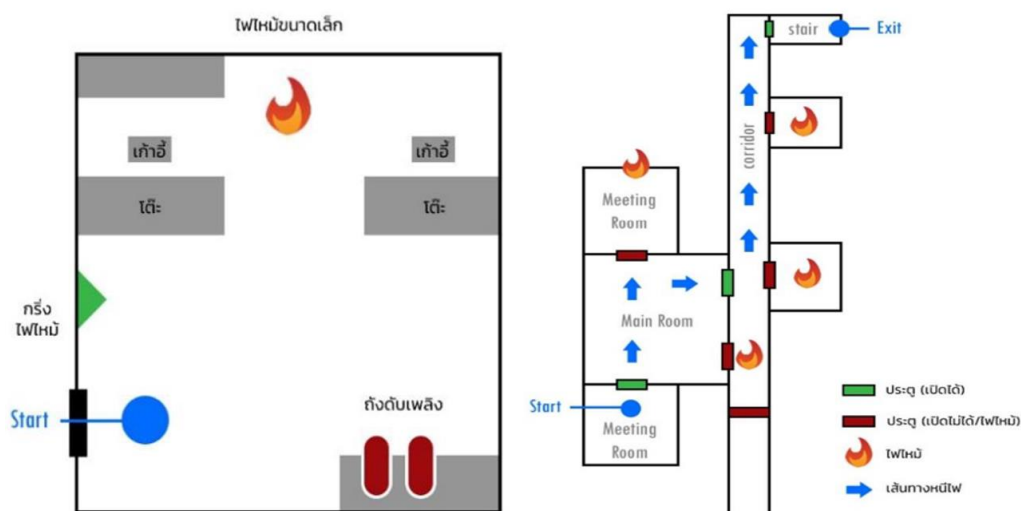

Fig 1. The example of game stage map design (left) the tutorial mode for basic fire training (right) the indoor fire survival mode.

2.2 Game evaluation

The evaluations of game quality and players' knowledge gained after playing the game were conducted using questionnaires. Both questionnaires were divided into 2 parts; the 5 Likert's rating scale part, which allows the participants to rate their opinions with each question, and the open-ended question part, which allows participants to provide additional feedback or suggestions. In the game quality questionnaire, the user interface (UI) design, the sound and graphic designs, the game system, and the content quality in the knowledge assessment questionnaire for the target group were asked. For the players' questionnaire part, it was done twice; before and after playing the game. They were asked about how much they understand the fire-preventing system in the workplace, how to use the fire extinguisher, and the process of evacuation. Three professional firefighters were selected purposively to evaluate the game quality as an expert on fire-fighting and 20 of 18-30 year-old individuals were chosen by accidental sampling to assess the knowledge they had learned both before and after playing the game as a target group.

3. Results

The Fire Safety VR Training Game was designed as a role-playing game with a first-person perspective through VR glasses. The story is about to survive from a fire at the workplace inside the building, which possibly happens in real life. The stages were developed in 3D graphics in a realistic style and intentionally colorful to capture the player's interest as shown in Figure 2. The game-inside objects were also designed to interact with the players based on the real situation, for example, when there is a fire, the player can push an alarm to let other people know about the fire, or while escaping, the player cannot touch the doorknob with a bare hand due to the high temperature, as shown in Figure 3.
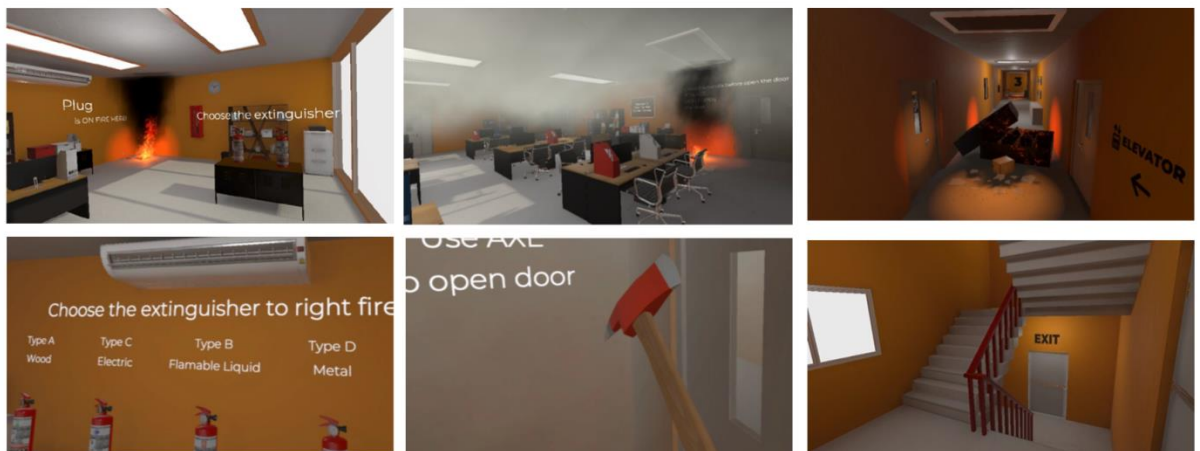

Fig. 2. Pictures of the game screens, (top-left to right) the fire in the meeting room, in the main room, and in the corridor, (bottom-left to right) the fire extinguisher, the provided tool (axe), and the fire exit, which is the game goal.
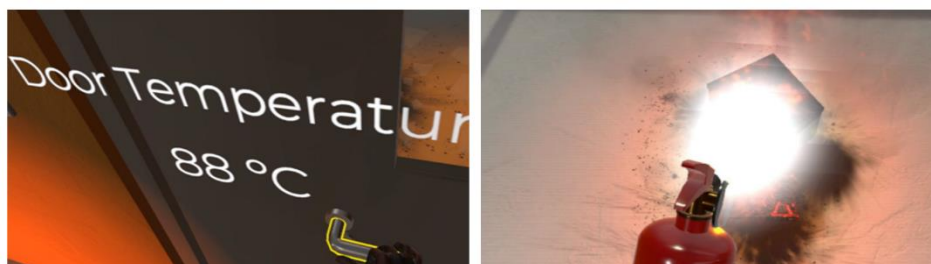

Fig. 3. The players can interact with the objects inside the game in a realistic way (left) the high-temperature doorknob will hurt the player if they are trying to touch it with their bare hand without any gloves (right) the fire extinguisher used to put out the fire.

The player must control their action through the Oculus Rift, a headset for VR games, and every action they did were collected, calculated into the score, and finally evaluated as a survival percentage, as shown in Figure 4.
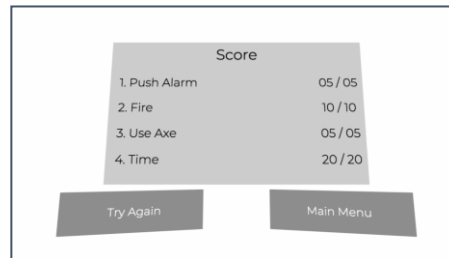

Fig. 4. The screen showed the score that the player get from the game events.

The overall quality of "the virtual reality serious game for fire safety training" was rated as very good (mean=4.55, S.D.=0.48) by three professional firefighters, as shown in Table 1. Interestingly, when comparing the knowledge achievement test of 20 players before and after playing the game, we found that the average score after playing the game is significantly higher than the average score before playing the game ($p < 0.01$), as shown in Table 2.

Table 1. The overall quality evaluation of the game by professional firefighters.

Evaluation Topic	Mean	S.D.	Quality level
The system of the game	4.50	0.50	Very Good
The graphic of the game	4.67	0.47	Very Good
The use of sound effect	4.33	0.47	Good
The user interface (UI)	4.67	0.47	Very Good
The game content	4.56	0.49	Very Good
The knowledge assessment questionnaire	4.56	0.49	Very Good
Average score	4.55	0.48	Very Good

The quality levels were separated by score: Very good (4.50-5.00), good (3.50-4.49), and fair (3.00-3.49). A lower score than 3.49 was counted as unacceptable.

Table 2. The comparison of the knowledge achievement test of before and after playing the game.

The score	N	Average score	S.D.	p-value
From pre-test	20	40.55	14.83	< 0.01**
From post-test	20	61.55	4.95	

** represents a significant difference between the score from pre-test and post-test.

Based on the findings, it can be stated that our VR game for fire safety training is successful and effective in terms of being an educational tool.

4. Conclusions

The appropriate fire safety training can reduce injuries and help increase the survival rate, especially in the case of emergency in high buildings [4]. However, fire safety training in real situations is expensive and time-consuming, even though it is considered the most effective way [5][6]. The key factors of this kind of behavioral skills training game are

the game immersion quality and the presence of participants so it should be designed and developed in a more realistic and immersive way [4].

This prompts us to introduce a new way for fire safety training through the VR serious game, which can give the player experience in a realistic way without any danger. The players have to make a decision depending on the events provided in the game. This can practice them to be ready when they have to face a sudden emergency. In addition, this game was developed in a first-person perspective style and players can freely control their actions by using a controller. Interestingly, it was evaluated by both professional firefighters and inexperienced players as an effective tool to prepare for fire safety training. Based on the test score before and after playing the game, it is shown a significantly increasing score on the post-test when compared to the pre-test.

In future research, it is recommended to investigate the effectiveness of combining the game with on-site training in enhancing individuals' knowledge and skills pertaining to fire safety.

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