Earthquake Safety VR – Enhancing Earthquake Awareness by Virtual Reality

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Abstract

This project is an educational simulator, provides real life earthquake experience in an immersive virtual reality (VR) environment in order to enhance users' awareness of earthquakes and improve users survival possibility if an earthquake hit suddenly. A survival score is calculated based on user behavior. User study shows that all users improved their scores after training; however, our sample group is not large enough to make scientific claim due to time constraint.

Keywords: Virtual Reality. Earthquake. Education

1 Introduction

Over the years, millions of lives were taken by earthquakes. On September 21, 1999, an earthquake of 7.6 magnitude struck whole island of Taiwan, China. It caused 2,400 deaths, 10,700 injuries, and destroyed over 8,500 buildings [1] in (Figure.1). On May 12, 2008, an 8.0 magnitude earthquake struck Sichuan, China; caused 70,000 fatalities and millions of people wounded [2]. Another one on March 11, 2011, a 9.0 magnitude earthquake assaulted northeastern Japan. With the tsunami following afterward, over 27,000 people were reported killed or missing. Furthermore, the earthquake and tsunami also brought a nuclear crisis at the Fukushima Nuclear Complex [3]. According to a summary, there have been 46 significant earthquakes around the world with death tolls exceeding 100 since 2000 [4], let alone millions of people who were traumatized from these tragic nature hazards.

However, some of these injuries and deaths could be prevented if they have enough awareness about earthquake safety procedures. Like don't try to go outdoors if you are inside a building, stay away from windows, fireplaces and heavy furniture, get out of the kitchen and so on [5].

Therefore, we decided to develop an earthquake simulator to provide the users necessary earthquake safety knowledge and train the users to be more prepared when earthquake happens.

Figure 1: Briefly scene of Taiwan Earthquake 1999 [1].

2 Related work

Generally, earthquake education is executed by schools. The most universal method is to make a school-wide exercise. However, it takes a lot of resources (mainly on time) to mobilize people to participate in this exercise. On the other hand, it is hard to make a deep impression on individuals; because it is abnormal, and people cannot relate to it. Most trainees in an exercise do not have a recognition and self-definition of the danger of earthquake. Thus, this method could lead to poor result on constructing people's earthquake awareness.

Nevertheless, we found several previous works attempted to raise earthquake awareness through different methods. Navakanesh et al. tried to use documentary movies to educate people in Southeast Asia [6]. H. Liang developed a VR application to train evacuees in an earthquake [7].

We are inspired by Dr. Hodges's contribution on Exposure Treatment using virtual reality [8][9][10]. We believe educate people through VR can improve efficiency not only on time saving but also on strengthen people's awareness of earthquake. Individuals can use this VR as part of their earthquake experience. Thus, with a better recognition of earthquakes, these people can response faster and have more possibilities to survive during a real earthquake.

3 System Design

3.1 Virtual Environment

We designed an enclosed indoor environment to simulate a situation of earthquake happening while user is at their home in (Figure.2). This scenario contains a living room, an integrated kitchen-dining room, a bathroom, two balconies, and two bedrooms (one with closet).

Most objects were modeled by using Blender, and then integrated into Unity which is the general developing platform. Objects were assigned with a value to evaluate users' performance (explained in 3.4) and follows Newton's Law of gravity by using default Unity physics engine in (Figure.3). Thus, when an earthquake happens, we could see things falling off randomly just like what would happen during a real earthquake.

Figure. 2 User's View of part the scene

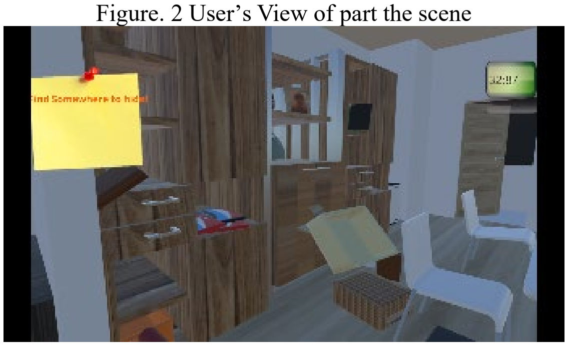

Figure. 3 Objects falling off

3.2 User Interface

We used HTC Vive to integrate with our project to provide an immersive environment. With the help of Steam VR SDK, users can alter view through rotating head-mounted display, move and interact with objects inside the virtual environment via hand-held controllers.

In order to acknowledge user's time left to survive an earthquake, a timer is generated at the top right corner of the screen. Timer is not activated at the beginning of the program. As soon as the earthquake begin, it starts to count down for 40 seconds.

Also, on the top left of the screen, there is a tip sticker as another visual interface to provide information that could assist users. The contents of the tip sticker are different base on different application modes (explained in 3.3).

Besides the virtual environment, we designed two simple scenes called Menu in (Figure.4) and Result in (Figure.7) as exterior interface pages. Menu is the beginning interface, user can switch modes or quit. Result is the interface generated after simulating, it consists of a "Survival Score" based on user's action in this test scenario, and buttons to return to beginning menu or quit.

Figure. 4 Menu Interface

3.3 User Mode

There are two modes in this application: Tutorial mode and Test mode.

In Tutorial Mode in (Figure.5), users can be trained here on controls and explore the environment. Neither earthquake nor timer are activated in this mode. Once tutorial tasks completed, user can decide to keep exploring the room or return to Menu page.

In Test mode in (Figure.6), where every feature is switched on. There will be a short time at beginning for user to quick explore the environment. When earthquake starts, user should find a safe place to hide before the timer counts to zero. When time is up, result page will automatically appeal.

Figure. 5 Part view of Tutorial Mode

Figure. 6 Part view of Test Mode

3.4 Scoring System

As mentioned in part A, each object was assigned with a value to represent their effect on user's safety. To indicate objects' effects on users more appropriately, objects are also allocated with a value called Affect Range. If a user is within one object's range, then a score measured and degraded by distance from the user to object itself could be added to user's performance score. However, if a user is outside this object's Affect Range, there should be no influence on user, thus, score for user should be 0 here. A score added to user due to one object should be:

$$V_{UO} = \frac{D_{UO}}{R_{OBJ}} * V_{OBJ}, D_{UO} \leq R_{OBJ}$$

$$V_{UO} = 0, D_{UO} > R_{OBJ}$$

While V_{UO} is the score by the relationship between user and object, D_{UO} as distance between user and object, R_{OBJ} as range of the object and V_{OBJ} as object's value.

For each frame, every object should generate a score on user to present how many affections on user in that situation. Thus, the sum score of a user explains user's summary reward or penalty due to user's behavior: Survival Score. Survival Score on each frame should be:

$$V = \sum_{\forall OBJ} V_{UO}$$

It starts to calculate when earthquake begins in Test Mode. Refreshed frame by frame to keep tracking user's current status. After earthquake, the Survival Score of last time frame will be transmitted into Result interface and presented to users. With some helpful hints to improve score in (Figure.7).

Figure. 7 Result Interface with Survival Score on it

4 Procedure

We recruited 12 volunteers in Clemson University including graduate students and undergraduate students to participate in our experiments. They are age between 18 ~ 29, and from different region or background.

For each participant, after a quick pre-session questionnaire to identify their backgrounds, we gave them three tasks to do, which called "3-Step Test". After they finished the tasks, a comparison of their performance scores in different tests will be used as our experiment results.

4.1 Pre-Session Questionnaire

Before the tests start, we made a series of short questions in order to gain their background that may affect their earthquake awareness. Here are the short questions:

How old are you?

Are you from an earthquake active region?

Have you experienced an earthquake before?

Do you have any knowledge of earthquake safety procedures?

4.2 First Test

At the beginning of the experiment, there will be a short time for participants to familiar with the environment. In order to avoid deviations in results caused by unfamiliar environment and to simulate earthquake scenario in real world, users have some time to explore but they are not aware when the earthquake will start. Then the earthquake will come and continue for 40 seconds. It will become stronger and stronger when time go by. During this time, participants must complete what they should do during an earthquake in the real world (ex. turn off the stove, open the door) and successfully find a shelter. They should try to avoid objects (ex. Windows, cabinet) that could expose themselves to danger in their escape path.

4.3 Tutorial

After the first experiment, they will enter the Tutorial mode. There will be no earthquake in the tutorial mode and timer is turned off. In this mode, there will be tips and earthquake safety procedures to guide the user. There is a checklist at the end, users have to complete specific tasks to finish what is on the checklist. Finally, users can exit tutorial mode after completing all tasks.

4.4 Final Test

After tutorial mode, the final test starts. It's exactly the same as the first time and see how much they have improved after tutorial. When users finish, we will record their survival scores.

Finally, we will ask users for feedbacks, and analyze participant data.

5 Result

From the results, we found out that everyone did a better job on the Second Test after completing the Tutorial tasks. The overall mean score of the first test score is 45.3 and mean score of second test is 114.0 in (Figure.8).

We tried to analyze results with weather or not they had prior experience of earthquake. Looking at result of people who had experience in (Figure.9) we see that the mean score is 66.8 and those without experience is 30 for the first test, which brings a 36.8 gap. However, with the assistance of our Tutorial, both experienced and non-experienced users get an average score over 100, and the gap between these two group shrinks too in (Figure.10).

Figure. 8 Overall Scores of participants

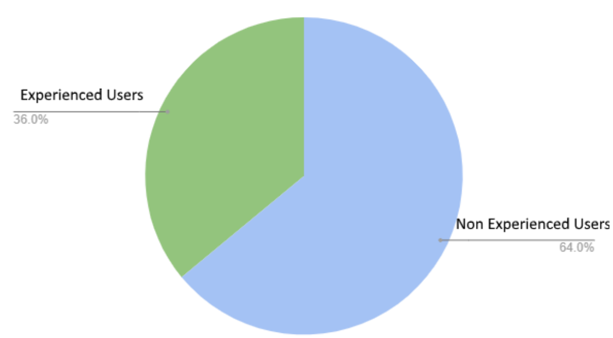

Fig. 9 Ratio of real earthquake experienced and non-experienced users

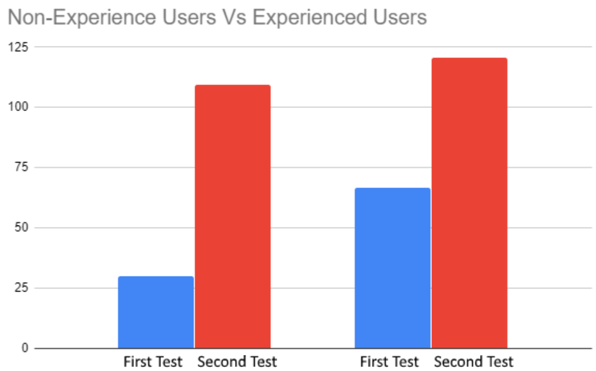

Fig. 10 Comparison of Average Score based on experienced and non-experienced users

6 Future Work

Firstly, we want to build more features visually. Our character could have more actions like seating and crawling. Magnitude of the earthquake could be various every time. User could learn more via experiencing earthquakes under different magnitude.

After users could perform more actions, we also want to develop our system to make it looks more professional. Our future Scoring System should contain more components and features such as a relationship with user movements and a bonus based on reaction time.

At last, we hope our approach could be widely used in general earthquake education in primary school. Research shows that it is necessary to train and raise earthquake safety awareness as early as possible, and primary schools are the best place for this[11].

7 Conclusion

From our results there seem to be a correlation between the score(VR safety score) and those who have experienced an earthquake and those who have not, but the difference is small compared to the difference of the first test and second test in (Figure.10). The great improvement in even experienced users mean that it is an effective solution to educate people about earthquake safety.

Although there are other solutions to educate people there are a few features that set VR simulations apart. The simulation provided an easy way for people to visualize what occurs in an actual Earthquake as well as what to do. We believe that this is a more effective educational experience than reading from a book and far more interactive than watching a video.

The Earthquake Safety VR was designed to emulate a real life situation however it was limited by our current technology limitations and resources. In the future we expect Earthquake Safety VR's to be much more relevant and accessible for use in safety protocols. In conclusion, we believe that Earthquake Safety VR's will be one of many future educational tools used to improve educational experience..

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