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Prototyping of an Earthquake Evacuation Learning Game with VR Reproducing the Environment That Is Familiar to Learners

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Abstract: Recently, big earthquakes happen worldwide, and UNDRR adopted the Sendai Framework for Disaster Risk Reduction. Learning about earthquakes is getting more important. When learning about disasters, it is important to treat them as it is their own problem. For this, Mitsuhara proposed the GLI (Global, Local, and Individual) model of disaster education. To make learners learn as it is their problem, we need to develop an environment that they can perform the local and individual disaster learning. It is also important to keep learning about disasters. For this, we prototyped evacuation learning game with VR, and the game reproduces the environment that is familiar to learners with VR to achieve local and individual level disaster learning. In this study, we reproduced building No.5 in our university where students mainly used every day because the target students of the game are our university students. We also conducted a preliminary experimental evaluation of the learning game. The results showed that (1) the reproduced environment can encourage learners to imagine a situation that an earthquake happens at the place that is familiar to them, (2) the game factors may motivate learners to learn about disasters.

Keywords: Disaster Education, Game-based Learning, Virtual Reality, Learning Assist System

1. Introduction

Recently, big earthquakes happen worldwide, and UNDRR (2015) adopted the Sendai Framework for disaster risk reduction. Learning about earthquakes themselves and how to evacuate from earthquakes are imperative and developing a learning environment of an earthquake is an important issue.

It is also essential to keep learning about disasters because we cannot take appropriate decisions at disasters if we do not remember the knowledge about disasters at any interval. Besides, learners must participate in disaster education as it is their problem. For this, Mitsuhara (2018) proposed the GLI (Global, Local, and Individual) model of disaster education, which each level is defined by being focused on what people need to learn. On the global level, disasters themselves are focused and people learn general knowledge. For example, if they learn earthquakes, they learn knowledge such as earthquake intensity and magnitude and how to keep safe, etc. Then, on the local level, a community that people belong to is focused and they learn how to apply the knowledge they learned on the global level to the community. Finally, on the individual level, people learn how to expect what will happen and how to behave as an individual person when a disaster occurs in the community.

For learning about disasters as their own problem, we considered that learning on the local and individual level is important. Therefore, we aim to construct a learning platform where learners can perform local and individual level disaster learning. In order to achieve local and individual level disaster learning, we reproduce an environment that is familiar to learners with VR. Freina and Ott (2015) reported that immersive VR can offer the following advantages; VR can allow learners to have partial immersive and can support providing a safe training environment avoiding real danger. In addition, Krokos et al. (2018) revealed that immersive VR can assist learners in having better memory ability compared to non-immersive VR environment. Thus, we reproduce an environment with VR.

Many disaster learning systems have been developed, but most of them are not for the local and individual level learning (for example, the reproduced environment is an ordinary building). Li et al. (2017) developed the learning system for earthquake safety training through the virtual drill. In this

system, learners undergo training in the reproduced room with VR. The learners attempt to detect potential danger and a way to protect themselves through an immersive training experience. Ruffino et al. (2018) developed the simulation and serious game for fire evacuation training. This game is designed to learn fire evacuation from a building in urban areas with immersive VR and serious game approach. However, the reproduced places on their learning system are general buildings so that learners cannot learn on the local and individual level. Hence, we reproduce an environment that is familiar to learners.

In addition to the above, we adopt the game-based learning approach to motivate learners. Even if we develop a good learning environment, it will not have enough learning effectiveness if learners do not learn repeatedly. Many research (like Perrotta et al. 2013) reported that game-based learning and gamification approach are effective to motivate learners. So, we adopt a game-based learning approach and will implement game factors to the learning platform. Therefore, in this research, we prototype the learning game that consists of an environment that is familiar to learners and game factors to motive them to keep learning. We also conducted a preliminary evaluation of the learning game.

2. Consideration of Learning Content

2.1 Stage in the Learning Game

As mentioned in the introduction, we aim to achieve the situation that learners can learn earthquake evacuation on the environment that is familiar to learners. Therefore, the stage in the learning game is the building No.5 in our university reproduced with VR by Unity (Figure 1).

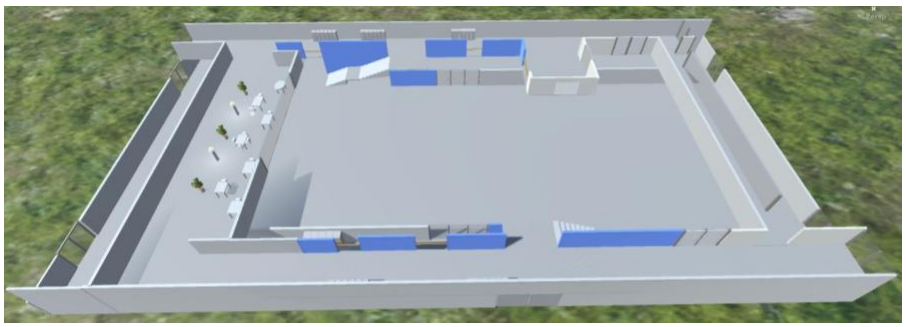

Figure 1. The Building No.5 reproduced with VR

2.2 Game Features in the learning game

2.2.1 Timer and Safety Percentage

The learning game has a timer so that learners can see the time that they spent to evacuate. The time is recorded and used by the evaluation function mentioned later. When we evacuate, not only fast but also safe evacuation is important. So, the learning game has the parameter that shows how safe learners are evacuating. This parameter is called “safety percentage.” safety percentage will decrease when they take inappropriate actions such as not hiding under the table when an earthquake occurs, going near fragile things like windows, and running when they evacuate. The game is over if the safety percentage becomes 0%. We expect that showing decreasing safety percentage facilitates learners to learn inappropriate action in earthquake evacuation.

2.2.2 Dangerous Action Count and Restart Function

If learners take a dangerous action that may lead to death, the learning game will restart, and the learners have to starting again from the start point. Also, when they take a dangerous action, the number that shows how many times they took dangerous actions (dangerous action count) will increase. Figure 2 shows the screen after restarting. The alert about the dangerous action that they took is shown. Then,

they need to start again, being careful of dangerous actions. This time, we employed taking an elevator as a dangerous action in the learning game. Thus, when learners get closer to an elevator, the dangerous action count will increase, and the learning game will restart. The game will be over when the count becomes three.

Figure 2. The ScreenShot after Restarting

2.2.3 Evaluation Function

The learning game has an evaluation function to get learners motivated to achieve better evacuation result. The function evaluates their evacuation judging from the Safety Percentage and clear time after they played the learning game. Also, the learning game records their best score.

2.2.4 Achievement List

The learning game has an achievement list to encourage learners to learn repeatedly. We expect that learners consider better behaviors on evacuation to clear assignment in the achievement list. Figure 3 shows the achievement list. When they achieve an assignment, Clear is shown on the right side of the list. The assignments in the list get more difficult from the first one to the fifth one. We expect that including the conditions (such as clear time and safety percentage) in the assignment statement facilitate learners to consider such as what better actions on the evacuation are, how to evacuate more safely.

Figure 3. The Achievement List

3. Learning Flow with the Game

In this chapter, we explain the learning flow with the learning game. This game is implemented with Unity for VR. Learners put Head Mount Display (HMD) and use a controller to play the learning game (HMD is Oculus Rift, and the controller is Oculus Touch).

When learners start the learning game, the screen shown in Figure 2 but without an alert will appear. The learning game starts at the students' lounge which is on the second floor of the building No.5 (Left side of Figure 1). First, leaners hide under a table following the instruction until the tremors of the earthquake stopped. If they do not hide this time, the safety percentage will decrease. After stopping the tremors of the earthquake, learners start the evacuation. They are going to find doors to the outside, which are on the first floor of the building. If they can find one of them and can get out of the building, the evacuation is a success. As mentioned in chapter 2, the safety percentage will decrease if they run or go near windows, and the dangerous action count will increase, and the learning game will restart if they get closer to an elevator. The game is over if the safety percentage becomes 0% or if they do dangerous actions three times. If they succeeded in an evacuation, the result screen (Figure 4) will appear, and learners can see an evaluation. The best score is updated if the score of the learning game is higher than the current best score.

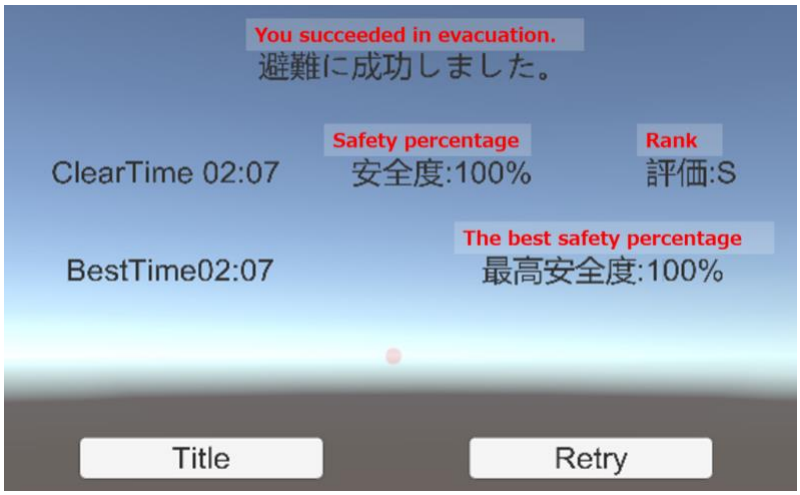

Figure 4. The Result Screen

If learners succeed in an evacuation, they select whether they play the learning game again or they go back to the title screen on the result screen. If they failed to evacuate, they select whether they play the learning game again or they go back to the title screen on the game over screen. After playing the game, they can check the achievement list (Figure 3) to achieve better evacuation on the next learning. Repeating this flow, learners can learn how to evacuate from the building No.5 repeatedly.

4. Preliminary Experimental Evaluation

4.1 Hypotheses

We have the following two hypotheses to verify the effectiveness of the Learning Game:

Hypothesis 1: Learning with a reproduced environment which is familiar to learners assist them in imagining what is going happen when an earthquake occurs.

Hypothesis 2: The game features can stimulate their learning.

4.2 Overview of the Evaluation

First, we show the manual of the learning game and explain what learners should do in this evaluation. Then, they put the HMD and practice usage of Oculus Touch with practice mode. When they think they

practiced enough, they start the earthquake evacuation learning game. They play the learning game twice, regardless of succeeding to evacuate or not. After playing the learning game, learners answered the questionnaire for the learning game on Google Form. The questionnaire is a four-grade evaluation; four is good, and one is poor. Twelve engineering students participated in this evaluation.

4.3 The Result and Considerations

4.3.1 The Result of the Questionnaire

Table 1 shows the results of the questionnaire. The numbers colored with red insist positive, and the numbers colored with blue insist negative. The totals may not become 100% due to rounding off.

Table 1
The Contents and Results of the Questionnaire

Questions	4pt	3pt	2pt	1pt
Q1: Could you imagine a situation that an earthquake happens at the place that is familiar to you by this experience?	0%	75%	25%	0%
Q2: Did you think that the things that you learned with this learning game are useful for real evacuation?	8.3%	41.7%	50%	0%
Q3: Did showing Safety Percentage and restart function assist you in learning inappropriate actions and dangerous actions?	33.3%	50.0%	0%	16.7%
Q4: Did you think you want to learn repeatedly by evaluation function and best score recording functions?	16.7%	66.7%	16.7%	0%
Q5: Did the achievement list assist you in learning with this game repeatedly?	8.3%	83.3%	8.3%	0%
Q6: Is the quality of the game (e.g., playability, user-interface, and so on) good?	25%	41.7%	25%	8.3%
Q7: Did you think the learning game made you think that you need to keep learning about disaster?	16.7%	66.7%	16.7%	0%

Moreover, some learners described the following opinions in the free describing field:

- It is better if you can make it clear where the exit is.
- I little wonder about going through the goal.
- I felt that the walking speed in the learning game is different from that in the real world. It should be a little faster.
- I wanted some hints like when we need to reset the learning game.
- It was not clear where the exit is, so it is better to use something like a maker to make it clear.
- It was not clear where the exit is. The walking speed is too slow so that I wanted to run while I know it is dangerous.
- It is better to make it clear where the exit is.

4.3.2 Consideration of hypothesis 1

Q1 and Q2 correspond to hypothesis 1. Q1 is a question to check the environment that is familiar to learners reproduced with VR encourages learners to imagine what happens to the familiar place if an earthquake occurs, and Q2 is to check that learners learned with this learning game are useful for actual earthquake evacuation. 75% of learners answered yes on Q1, while the ratio of yes and no is half and half. We consider why we got the answer on Q2; this is because the reproduced building No.5 is not perfectly reproduced and the learning game does not have the function to provide let the learners learn the features that people have to do in actual earthquake evacuation such as rescuing wounded people and appropriate actions when firing and/or blackout happens.

From above, the learning game can encourage learners to imagine what happens to the place that is familiar to them if a big earthquake occurs, but learners cannot learn actual behaviors that they have to do in earthquake evacuation. Thus, hypothesis 1 is partially supported.

4.3.3 Consideration of hypothesis 2

Q3, Q4, and Q5 correspond to hypothesis 2. Q3 is the question to check that showing Safety Points and restart function assisted learners in learning inappropriate action and dangerous action. 80% of learners answered that those features assisted their learning. Q4 is to check evaluation and best score recording functions encourage to learn repeatedly and Q5 is to check the achievement list encourages to learn repeatedly. Nearly 85% of learners had positive answers on Q4 and nearly 90% had positive answers on Q5. Thus, it is suggested that the game features stimulate learning. Thus, this result can support hypothesis 2.

4.3.4 Other Discussion from the Results on the Evaluation

From the result of Q6, only 60% of learners had positive answers. This is not as high percentage as other question except Q2. Besides, from the opinions in the free description area, they described the negative opinions about the quality of the learning game. This result means that the learning game should be refined to have better quality. Also, this results in the lower satisfaction on Q2. However, 75% of learners had positive answers on Q1 even the learning game does not have good quality. These results may lead that reproducing the place that is familiar to the learners and developing the environment that they can practice earthquake evacuation on their familiar place are effective to encourage learners to imagine a situation when a big earthquake occurs even the quality of the learning game is not necessarily good. We consider they could have achieved earthquake evacuation learning on the local and individual level.

Considering the result of Q7, we thought Q7 was too general so that the question does not evaluate any portions of the learning game. However, this question asks that the learning "game" can motivate learners. Thus, We consider that this result shows the effectiveness of Game-based Learning.

5. Conclusion

In this research, we prototyped an earthquake evacuation learning game with VR. The learning game aims to learn earthquake evacuation on the environment where learners are familiar. The learning game has game factors: safety percentage and dangerous action count which encourage learners to learn inappropriate actions on earthquake evacuation, the restart function, the evaluation function, the achievement list. As future work, we will add more situations that may happen in earthquakes such as fire, blackout, and rescuing wounded people. Besides, physical movement in the learning game is not perfect. We will handle both problems of learning contents and game quality.

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