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Evaluation of the Effect of VR Disaster Experience in Familiar Environment

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ABSTRACT

The purpose of this study is to evaluate how the participants' awareness of disaster prevention, such as disaster risk perception and disaster prevention behavioural intention, improve when they experience the VR disaster in a familiar environment like their own room. In the experiment, participants were asked to take pictures of the environment in which the participant spend their daily lives and to experience virtual earthquake and fire in the familiar environment created from the pictures and in the non-familiar environment. After experiencing each disaster experience environment, participants were asked to answer a questionnaire about their awareness of disaster prevention, which included a sense of reality, a sense of fear, a sense of familiar environment, communication intention, disaster risk perception, anxiety and disaster prevention behavioural intention to compare the effects of each disaster experience environment on the awareness of disaster prevention. In the results, it was found that experiencing VR disaster in a familiar environment may trigger people to imagine that disaster may actually happen to them, and may increase their awareness of disaster prevention. However, it was also suggested the possibility that people are more likely to notice unnatural places in the experience because they usually see the environment repeatedly.

Keywords: Virtual reality, Disaster experience, Disaster prevention, Psychology

INTRODUCTION

The number of natural disasters has been increasing in recent decades, and the amount of damage becomes enormous. To reduce the damage, it is crucial that people become more aware of disaster prevention and take action for disaster prevention and mitigation. As disaster education to awareness, a method using virtual reality (VR) (Xiaoli et al. 2015) (Yamashita et al. 2017) has been attractive because the VR disaster experience is a cost-effective solution and is easy to deploy. It can also reproduce disasters that are difficult to experience in reality, such as fire. However, in conventional VR disaster experience systems, it is possible to experience only a specific environment that the designer has selected and created in advance. The environment is often different from the environment in which the experiencer spend their daily lives. Therefore, it was difficult to feel a sense of reality and fear that a disaster might actually occur. In addition, from the viewpoint of reviewing disaster countermeasures, there were few points that could be used as references.

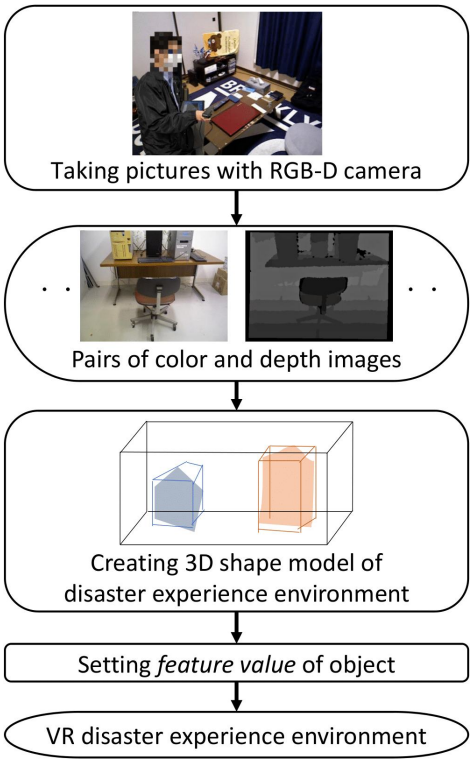

Figure 1: A flow of VR disaster experience environment construction.

In order to solve this problem, the authors have developed a system that automatically creates a VR space that enables users to experience disaster based on images captured by cameras with the 3D reconstruction method (Asaba et al. 2021). This system makes it very easy to experience disaster in the environment, which experiencers normally live in, constructed from pictures taken by them. It may raise awareness of disaster prevention because they can know how their room becomes in disaster. It is not clear, however, to what extent the experience of a disaster in a familiar environment is effective, or how the psychology of the experiencers changes when they experience a disaster in a familiar environment.

The purpose of this study is to evaluate how the experiencers' awareness of disaster prevention improve when they experience the VR disaster in a familiar environment like their own room. In this study, earthquake and fire are treated as disasters to be experienced.

CONSTRUCTION OF VR DISASTER EXPERIENCE ENVIRONMENT

Figure 1 shows the flow of the construction of the VR disaster experience environment in this study. In this method, the indoor environment of the target of the disaster experience is captured multiple times from various angles with RGB-D camera. Then, 3D shape models of the disaster experience environment, which are polygons representing the colour and shape of 3D objects, are created with pairs of colour and depth images. In this process, we utilize

Table 1. A relation between feature values and object's behaviours in VR disaster experience.

Disaster	*Feature values*	Object's behaviour
Earthquake	*Proportion of material* (glass/wood/metal/plastic)	Sound of collision and rupture
Fire	*Flammability*	Non-flammable, slowly flammable, well flammable and intensely flammable
	Proportion of material (glass)	Sound of glass rupture

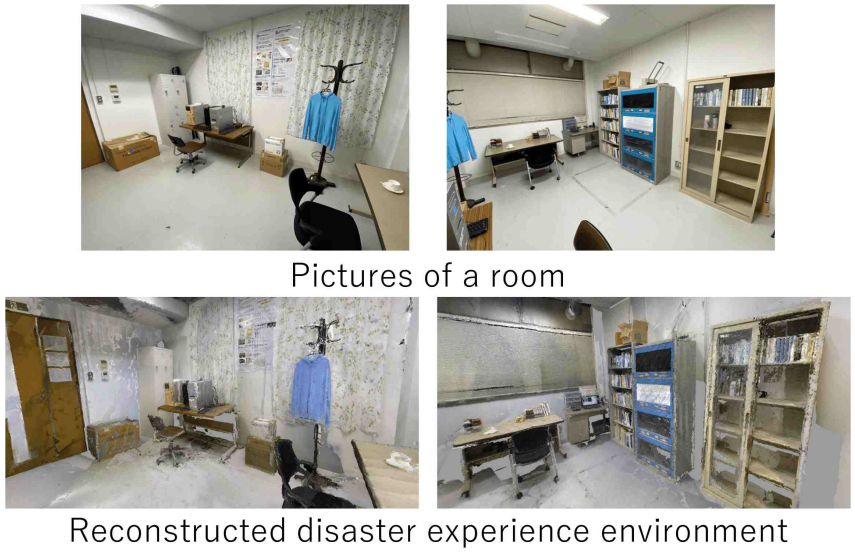

Figure 2: Pictures of a room (up) and reconstructed disaster experience environment (down).

our system (Asaba et al. 2021) for image denoising and creating 3D point cloud, Colmap (Lutz et al. 2016) for tracking and MeshLab (Cignoni et al. 2008) for converting 3D point cloud into 3D shape model. Next, we set *feature values* that determine the behaviour of the object during the simulation. Feature values are the values that represent the physical behaviour features of an object, which consist of *proportion of material* and *flammability* (Asaba et al. 2021). Table 1 shows the relationship between *feature values* set for the earthquake and fire disaster experiences and the corresponding object behaviour. In this study, we set *feature values* for each of objects manually based on the material and intended use of the object.

We described an example of the constructed disaster experience environment below. In this study, we used Unity version 2019.3.15f1 (Unity Technology), which can easily simulate flames, smoke, etc. that are necessary for constructing the disaster experience environment. And ASUS XtionPRO LIVE (ASUS) was used to photograph the indoor environment for the disaster experience. Figure 2 shows photographs of the actual room and the 3D shape models of disaster experience environment. As for the earthquake experience

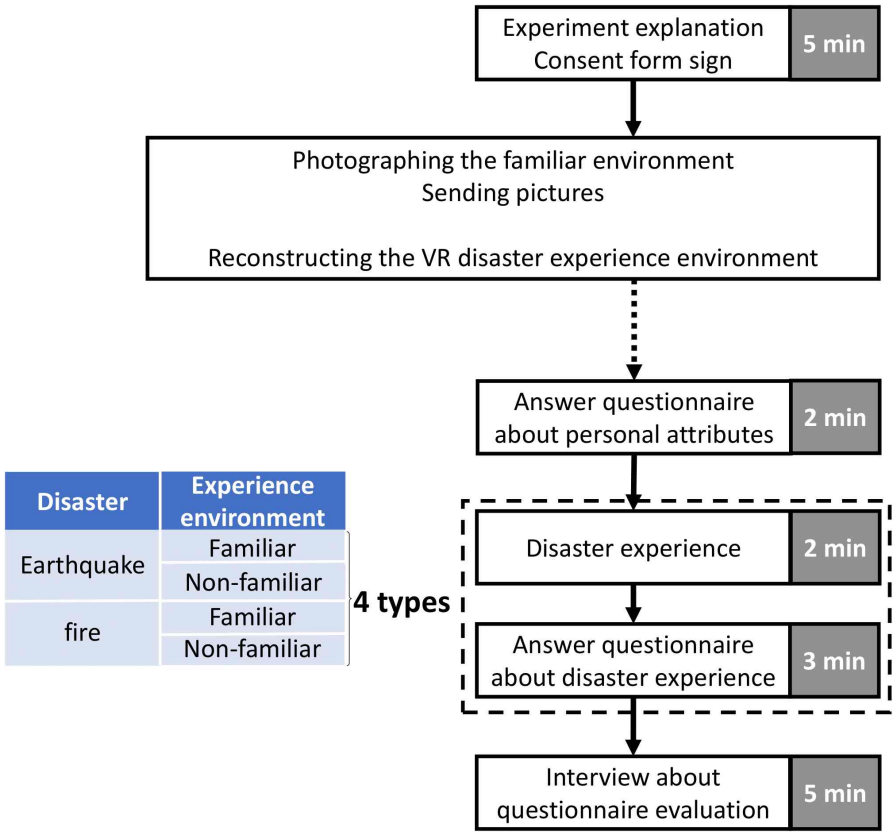

Figure 3: The procedure of the evaluation experiment.

environment, the earthquake shaking was reproduced by using the earthquake acceleration data that was created by measuring the shaking of an actual earthquake as the acceleration of the 3D shape model of the object and the viewpoint. This system applied the acceleration data of Great East Japan earthquake, which is available from the National Research Institute for Earth Science and Disaster Resilience (NIED, 2019). As for the fire experience environment, smoke is generated to spread from a high place as time passed. In addition, by setting the source of the fire, the fire will ignite from that object and spread to objects placed nearby. The source of fire is based on the number of fires by cause in the White Paper on Fire Service published by Fire and Disaster Management Agency (FDMA).

EVALUATION EXPERIMENT

The purpose of this experiment is to evaluate how the participants can raise their awareness of disaster prevention by experiencing a VR disaster in a familiar environment. This experiment was conducted with the approval of the Research Ethics Committee for Human of the Graduate School of Energy Science, Kyoto University.

The procedure of this experiment is shown in Figure 3 and described in detail below. In the experiment, the experimenter first explained the outline

Figure 4: Pictures of a room (up) and reconstructed disaster experience environment (down).

of the experiment to the participants and that the participation in this experiment was voluntary, and they signed a consent form confirming their cooperation in the experiment room. Then, they were asked to take pictures of the environment in which they normally live and to send pictures to experimenter. On another date, they were asked to come to the experiment room again and to answer questionnaires regarding their personal attributes, such as gender, age, whether or not they have experienced earthquakes or fires, and whether or not they have suffered psychological trauma as a result of these disasters. Next, they were asked to wear HMD (Oculus Rift) and to experience virtual earthquake and fire in the familiar environment created from the pictures and in the non-familiar environment. After experiencing each disaster experience environment, they were asked to answer orally questionnaires about their awareness of disaster prevention displayed in the VR space with HMD on. The time required to experience one disaster experience environment was about 2 minutes, and the time required to answer questionnaires was about 3 minutes. This process was repeated for two types of disasters, earthquake and fire, and they experienced all of the disaster experience environments and responded to the questionnaires. After all the questionnaires were completed, if there was a difference between the responses to each item in the first and second questionnaires for each disaster, an interview was conducted to find out the reasons for the difference. In order to prevent the order effect of the experimental conditions from influencing the results, the order of experiences of earthquake and fire, familiar and unfamiliar disaster experience environments were counterbalanced.

We prepared the non-familiar disaster experience environment. In order to properly evaluate the effect of the familiar environment, which is the purpose of this experiment, it is necessary to minimize the difference in physical characteristics such as room size between the familiar and non-familiar environments, which may affect the results. Therefore, through a preliminary experiment, we set up the room shown in Figure 4 as the non-familiar environment with similar characteristics such as room size to the familiar environment.

Questionnaires About the Awareness of Disaster Prevention

We prepared the questionnaires about the awareness of disaster prevention below. The participants were asked to answer on a 7-point scale from "1: I

Table 2. Questionnaires of each disaster experience and evaluation targets.

Disaster	No	Question item	Evaluation target
Earthquake	1-1	The VR experience felt like a real earthquake	A sense of reality
	1-2	The VR experience made me feel fear	A sense of fear
	1-3	I felt like I was experiencing in a familiar environment	A sense of familiar environment
	1-4	I would recommend this VR experience to others	Communication intention
	1-5	Through this VR experience, I began to think that the possibility of major damage from earthquake was high	Disaster risk perception
	1-6	Through this VR experience, I was very anxious about what would happen if earthquake occurred	Anxiety
	1-7	Through this VR experience, I have come to want to take complete disaster prevention and mitigation measures on a daily basis	Disaster prevention behavioural intention
Fire	2-1	The VR experience felt like a real fire	A sense of reality
	2-2	The VR experience made me feel fear	A sense of fear
	2-3	I felt like I was experiencing in a familiar environment	A sense of familiar environment
	2-4	I would recommend this VR experience to others	Communication intention
	2-5	Through this VR experience, I began to think that the possibility of major damage from fire was high	Disaster risk perception
	2-6	Through this VR experience, I was very anxious about what would happen if fire occurred	Anxiety
	2-7	Through this VR experience, I have come to want to take complete disaster prevention and mitigation measures on a daily basis	Disaster prevention behavioural intention

don't agree at all" to "7: I agree very much" to the questionnaire items regarding the disaster experience environment. Table 2 shows the correspondence between the items in the earthquake and fire disaster experience questionnaires and the items to be evaluated. As for the questionnaire items, the sense of reality and the sense of fear felt through the VR disaster experience (hereafter, "a sense of reality" and "a sense of fear", respectively) were set. The sense of familiar environment to confirm whether the participants feel that they actually experience the disaster in a familiar environment (hereafter "a sense of familiar environment") was also set. In addition, according to the previous research, it was shown that when people's awareness of disaster prevention is raised through disaster education, they pass this information on to other people around them, such as family members, and

their awareness of disaster prevention also improves (Toyosawa et al. 2010). Referring to this result, whether the participants want to spread this experience (hereafter, "communication intention") was set as for the questionnaire item about the awareness of disaster prevention. And, disaster risk perception, anxiety about disaster and disaster prevention behavioural intention (hereafter, "disaster risk perception", "anxiety" and "disaster prevention behavioural intention", respectively), which Motoyoshi et al. identifies as deeply related to household disaster prevention (Motoyoshi et al. 2008), were set.

RESULTS AND DISCUSSION

In this experiment, 21 undergraduate and graduate students (11 males and 10 females) participated until now, while we planned 24 in total. They were from 18 to 27 years old (Mean = 22.1, SD = 2.24). A part of the interview responses is shown in Table 3, and a part of the free comments after the experiment is shown in Table 4.

Earthquake

We first discuss the responses of earthquake in Figure 5. The response of a sense of fear under the familiar environment is higher than that under the non-familiar one. As participate 16 stated, "I was terrified that familiar and thoughtful objects had fallen," it was supposed that a sense of fear increased because the environment was familiar to the participants.

The response of disaster risk perception under the familiar environment is also higher than that under the non-familiar one. As stated by participant 17, "I felt dangerous in my room because there were many things moving and falling," it was supposed that the participants could recognize the risk of disaster by experiencing a VR disaster in a familiar environment. However, as participant 16 stated, "Compared to when I actually experienced earthquake, I thought the way objects fell in my room was a little different," a familiar environment could make it easier for participants to notice objects which behave in an unnatural way.

As for anxiety, the response under the familiar environment is higher than that under the non-familiar one. Participant 19 commented, "I felt in fear for my life because objects fell from a high place in my room," while participant 9 mentioned, "I didn't feel anxious because I knew where to escape in my room."

The response of disaster prevention behavioural intention under the familiar environment is also higher. As stated in the interview, "I thought about what actions and countermeasures I would take if earthquake happened in my room" and "I was able to know areas in my room where countermeasures are inadequate, and I decided to take action," it was suggested that the damage by experiencing a VR disaster in a familiar environment can encourage people to take disaster-prevention measures.

Table 3. A part of answers of interview of participants.

Participant No.	Question No.	Response (familiar, non-familiar)	Answer of interview
3	1–7	6,5	I thought that my room is full of flammable objects, so I decided to take countermeasures.
4	2–6	4,5	I felt anxiety about the power strip, which is a fire hazard in a non-familiar environment, because it's also in my room and I don't know the signs of ignition.
5	1–7	6,2	I thought about what actions and countermeasures I would take if earthquake happened in my room.
9	1–6	4,5	I didn't feel anxious because I knew where to escape in my room.
16	1-2	7,4	I was terrified that familiar and thoughtful objects had fallen.
	1-5	4,5	Compared to when I actually experienced earthquake, I thought the way objects fell in my room was a little different.
	2-7	6,7	In terms of thinking about countermeasures, I thought it might be better to be in a non-familiar environment where I could see things from a dispassionate point of view.
17	1-5	7,5	I felt dangerous in my room because there were many things moving and falling in my room.
	1-7	7,5	I was able to know areas in my room where countermeasures are inadequate, and I decided to take action.
19	1–6	7,4	I felt in fear for my life because objects fell from a high place in my room.
21	2–2	6,2	Seeing the disaster in VR made me image what it would be like if it actually happened, and it was terrifying.

Fire

We discuss about the responses of fire in Figure 5. The response of a sense of fear under the familiar environment is higher than that under the non-familiar one. As participant 21 mentioned, "seeing the disaster in VR made me imagine what it would be like if it actually happened, and it was terrifying," it was suggested that experiencing VR fire in a familiar environment may increase a sense of fear more. However, some participants highly evaluated the VR experience in the non-familiar environment because of the fear of flames spreading around them and the source of fire.

In the responses of anxiety and disaster prevention behavioural intentions, there was not much difference between that the familiar and non-familiar environment. As stated by participant 3, "I thought that my room is full of

Table 4. A part of free comments of participants.

Participant No.	Free comment
2	The weight of the objects in my room was a little different from my senses.
4	Smoke and alarms terrified me. It would be even better if the flames could jump on me.
11	It would be very scary if fire started in a power strip while I am sleeping.
12	Smoke terrified me.
13	Flames spreading terrified me.
17	The chair in my room has casters, so I thought it might move a little more.
19	It was realistic to see shelf moving in my room that I hadn't taken countermeasures against. I think it would be more terrifying if I could actually feel the shaking.

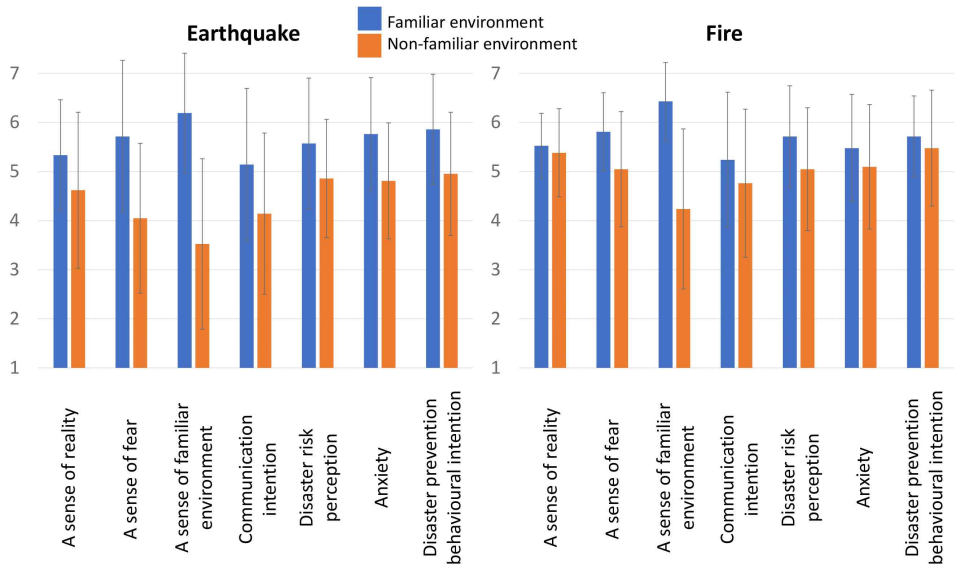

Figure 5: The responses of each disaster experience.

flammable objects, so I decided to take countermeasures," it was suggested that the awareness of disaster prevention could be improved by experiencing disaster in a familiar environment. However, as participant 4 and 16 mentioned, "I felt anxiety about the power strip, which is a fire hazard in a non-familiar environment, because it's also in my room and I don't know the signs of ignition" and "in terms of thinking about countermeasures, I thought it might be better to be in a non-familiar environment where I could see things from a dispassionate point of view," it was suggested that even VR experiences in a non-familiar environment could be helpful in disaster preparedness.

CONCLUSION

The results of the evaluation experiment showed that a familiar environment may trigger people to imagine that a disaster may actually happen to them, and may increase their awareness of disaster prevention. On the other hand, it is easy to notice unnatural behaviour of objects, which may reduce a sense of reality and lower the effectiveness, in the familiar environment than in the non-familiar one because they usually see the environment repeatedly.

Future work includes conducting evaluation experiments with up to 24 participants in total. In addition, we should construct the psychological model of the VR disaster experience in order to investigate how psychological factors such as a sense of reality and fear generated by the VR disaster experience relate to disaster preparedness.

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