Adaptive Virtual Reality Disaster Simulation for Community Training

Arianne Valencia
Department of Computer Science
University of the Philippines - Diliman
Quezon City, Philippines
asvalencia1@up.edu.ph

Mikayla Lopez
Department of Computer Science
University of the Philippines - Diliman
Quezon City, Philippines
mulopez@up.edu.ph

***Abstract*—The Philippines is a country prone to land, water, and weather phenomena—most of which are disastrous. Unfortunately, the country is not always fully equipped to handle such disasters. The lack of preparedness stems from the lack of disaster risk management (DRM) education; however, organizing DRM lectures and/or drills requires funding, logistical planning, labor, and time. For many years now, virtual reality (VR) has been being used to build immersive training simulations for training and learning purposes using minimal resources. It shows potential to be a promising alternative teaching method to bridge the logistical and educational gaps of the established DRM lectures, drills, and trainings.**

***Index Terms*—virtual reality, adaptive, personalization, disaster preparedness**

I. Background of the Study

The Philippines is an archipelago near the Pacific Ocean, making it very prone to land, water, and weather phenomena—most of which are disastrous. Statistically speaking, around 20 tropical cyclones enter the Philippine Area of Responsibility (PAR) every year, and according to the Philippine Atmospheric, Geophysical, and Astronomical Services (PAGASA), about 5 of them would be potentially destructive. Super Typhoon Yolanda, one of the worst natural disasters to strike the Philippines, had an official death toll of 6300 people, and affected over 16 million. Overall, the cost of damages caused by the super typhoon was around 95.48 billion (Rappler, 2016). In 2011, Typhoon Sendong had affected about 700,000 people, had 1901 casualties, and caused around 1 billion in total cost of damages.

Unfortunately, the country is not fully equipped to handle such disasters and, as a result, the most vulnerable of such events are the urban poor. Environmental hazards are not inherently disasters. They only become so when people in affected areas become unable to withstand or cope with their effects. Social inequality limits the poors access to secure housing, healthcare, education, etc. which places them in a position of vulnerability to hazards. For many of them, the losses they experience can have debilitating effects. While wealthier households may have the resources to recover and protect themselves more easily from hazards, a hazard affecting a poorer household might mean the loss of a means of livelihood or the total destruction of a home, leading to exacerbation of conditions of poverty (ACCORD, 2012).

Lack of resources is not the only factor to mediocre disaster response. Lack of preparedness also comes from the lack of disaster risk management (DRM) education. (Dalisay and De Guzman, 2016) However, organizing DRM lectures and/or drills requires funding, logistical planning, labor, and time (Commission on Audit, 2013). That is why the researchers looked to use virtual reality (VR) gaming as an alternative teaching method for DRM to bridge the logistical and educational gaps of the established lectures, drills, and trainings. (Hsu et al., 2013)

II. Objectives of the Study

This research aims to establish the following:

A) To develop a smartphone-based and immersive VR application designed and implemented with the following considerations:
  a) Content
    i) The application shall display environments simulating scenarios before and during a typhoon
  b) Personalized user experience
    i) Information shall be collected from the user, and the information collected will be used to determine the objects and associated events that are available in the indoor house environment for the user to interact with in several tasks, the contents of the supplies checklist that the user will be instructed to complete in-game, and the scene that will be given to the user as a simulation in the context of an incoming typhoon.
  c) Adaptive Environment
    i) The application shall use on-task adaptive mechanisms to alter the learning environment and to facilitate the users accomplishment of the tasks
    ii) The application shall make use of the following variables to create the aforementioned adaptivity:
      1) Time elapsed from last successful press of Action button (unless walking)
      2) The players in-game position (x, y, z)
      3) Number of incorrect attempts
  d) Data Handling

i) The application shall gather the following information from the user for the purpose of tracking user profiles:
   1) Number of members of the household
   2) Number of household members who need medication
   3) Number of household members who are children (below 18 years old)
   4) Socioeconomic self-categorization (poor or well-off)
   5) Possession of an LPG tank (owns or does not own)
   6) Availability of electricity (available or unavailable)
ii) The application shall save the users progress every 2 minutes, and after 15 minutes is up.
iii) The application shall keep in and access the collected user data from local storage.

B) Materials
   a) Google Cardboard-compatible head-mounted device (HMD)
   b) Smartphone with the following specifications:
      i) OS: Android 4.1 or above
      ii) Sensor: Gyroscope sensor

C) To conduct training sessions, as well as pre-test and post-test examinations to assess the users knowledge acquisition made using the application.

III. Scope and Limitations of the Study

This study focuses on implementing a personalized smartphone-based virtual reality (VR) application to be used as a tool for training individuals on how to properly prepare and respond to disaster risks. The application can be fully explored using any Google Cardboard-compatible HMD. It also contains a training module that shows scenarios before and during a typhoon strike. Simulations of scenarios after a typhoon occurs lie beyond the scope of this study due to the variability of the conditions that can arise after a typhoon subsides.

The application is deployed for use on Android, as most inexpensive smartphones in the market run on Android, and Unity3D with the Google VR SDK were utilized to develop the application. This paper, however, does not seek to evaluate the accessibility of virtual reality on Android in comparison with other virtual reality platforms.

An adaptive feature that calls the users attention and shows visual hints when the application detects inactivity or unresponsiveness from the user is implemented, to help the user focus on the tasks at hand rather than figuring out how to navigate the game.

Due to the absence of handheld and other external controllers, the user is limited to head movement/gaze, and the Action button on the head-mounted device as in-game controls. In addition, kinesthetic immersion is also unattainable without the appropriate hardware.

Respondents of the study are residents of Marikina City, Metro Manila, aged 18-30 years old. This city was chosen as it is the nearest city that is vulnerable to typhoons and floods. Before and after the use of the application, online pre- and post-tests were given to the user to assess what they have learned from the training modules. The questionnaires that were given to the respondents are meant to assess the effectivity of learning and the knowledge acquisition of the user from using the application, rather than to evaluate the adaptivity of the application.

IV. Significance of the Study

The study aims to expand the literature on disaster risk reduction training situated in a virtual environment. The application proposed in this paper will generally be modeled after typical conditions that arise in a community that is prone to flood hazards.

We aim to empower community members of the selected area by helping them understand typhoon and flood hazards, the national warning systems that are in place for these hazards, as well as practices that will help them secure their and their households wellbeing. The gaming experience is personalized for the user because the actions that one household can take to adapt to the risk of hazards varies depending on their capacity to do so, given their resources.

In addition, according to the situated learning theory as proposed by Lave and Wenger (1991), individuals learn effectively when placed in the context of the learning objectives. In the context of disasters, virtual reality has potential for training in how users can carry out relevant educational tasks in what appears to be a dangerous environment, without actually being placed in harms way.

Higher levels of immersion, as with VR, have positive effects on the memorization of procedures (Bowman et al., 2009). Immersive VR serious game (IVR SG) frameworks have the capability to generate realistic scenarios" and hazards, which in turn create more realistic feelings" in participants. The effect is to make preparation and evacuation simulation highly engaging so that participants can get better hazards perception and risk awareness.

V. Review of Related Literature

There have been countless papers that have looked into the use of virtual reality (VR) technology to build immersive training simulations for various purposes and fields, such as teaching equipment operation procedures (Jung and Joong Ahn, 2018) or safety in the workplace (Sankaranarayanan et al., 2017; Jorge et al., 2013). In fact, in a paper by Menin et al. (2018), they analyzed around 50 immersive simulations and found that most of those that were for learning and training purposes were fully immersive; that is, they made use of three-dimensional scenes displayed in a wide field of view, such as in head-mounted devices (HMDs) or cave automatic virtual environments (CAVEs) (Muhanna, 2015).

Why are fully immersive virtual reality a common choice of interface for training simulations? According to Bowman et al. (2009), higher levels of immersion have been proven to have positive effects in the memorization of procedures, which is often an important part of the learning objectives of a training simulation. In addition to this, gamified learning simulations in general have been found to increase knowledge retention as well (Farra et al., 2012; Menin et al., 2018). These two ideas are consistent with the Situated Learning theory by Lave and Wenger (1991) which argues that people learn the best when they are embedded into the activity, culture, and context of their domain. Learning is supported this way by allowing learners to use or develop the cognitive tools that would be necessary in an authentic relevant environment.

We can already see applications of fully immersive VR in disaster risk management training. The Red Cross/Red Crescent Climate Centre has developed several virtual reality games related to climate and disaster education, one of which places the user in charge of overseeing the ringing of alarm bells, approval of aid delivery, and delivery of supplies via relief truck, as they watch over the situation in flood-prone villages experiencing heavy rain. (Goering, 2016) While the previous game concerns itself with facilitating understanding in laypeople of the processes decision-makers need to go through in times of disaster, a Filipino-made virtual reality disaster simulation game named Minmin Escapes from Disaster, aimed to teach children (ages 4-8) and young adults (ages 19-21) to survive earthquakes and fires from the point-of-view of a regular person (Dumol et al., 2014). In Singapore, EON Reality and Iceberg Design were selected to develop a disaster simulation for EON Icube, a CAVE that utilizes what they call 4D effects", such as wind, for example, in addition to the virtual 3D environment. Their disaster simulation solution placed users in the middle of a disaster scenario to experience its effects in a realistic but safe way, which they claim may better prepare citizens to quickly and effectively react.

Developed prior to these applications were lower immersion virtual reality" simulations on desktop computer setups such as the John Hopkins Office of Critical Event Preparedness Response (CEPAR) VR-based training modules, which cover topics of triage, personal protective equipment and decontamination, as well as biological, chemical and radiological threats" (Hsu et al., 2013) and the VR simulations by Farra et al. of the same nature, meant to be used in conjunction with web-based modules designed for nursing students. Both used the game Second Life as a platform for building their scenarios.

Virtual reality for learning and training is not without problems. The use of VR applications, no matter the level of immersion, have been shown to improve learning compared to traditional methods of teaching. However, if the users have difficulty navigating inside the system, it would impose extra cognitive load on the user, on top of the effort that it would take for them to fulfill the learning objectives (Farra et al., 2012; Dumol et al., 2014; Chen et al., 2005). Another problem associated with VR applications in general, is VR sickness. One cause of dizziness in VR simulations is a low frame rate, ideally more than 30 fps (Ya Hu et al., 2018). VR sickness may also be caused by certain UI elements, such as a visual field range that encompasses the entire space around the user, for example. (Kim et al., 2017)

A. *Adaptivity in E-learning*

In a review of Adaptive e-Learning Environments by Khamis (2015), they were able to present various definitions of adaptivity, among them being the following from Kumar (2006):

> Adaptation system is the central component of any E-learning system and is responsible for tailoring learning materials or contents according to the learners style, profile, interest, previous knowledge level, goal, pedagogical method etc. to provide highly personalized learning sessions. Adaptive E-learning systems, deal with appropriate personalization and adaptation techniques (smart curriculum sequencing, navigation guidance, intelligent problem generation and analysis of solutions, adaptable interfaces, adaptive contents, etc.) in order to maximize the effectiveness of learning (Kumar, 2006 as cited by Khamis, 2015).

Khamis also presented two models that define the processes found in an adaptive system, both in agreement that adaptativity is an iterative cycle. Shute and Zapata-Rivera define an Adaptive e-Learning Cycle in four processes: (1) Capture, where cognitive or non-cognitive aspects of the learner can be acquired as information, (2) Analyze, where a model or representation of the student in the system is created or maintained using the information captured, (3) Select, where information or an adaptive decision is selected based on the student model, and (4) Present, where the information or adaptive decision is given to the learner.

Khamis also cited Park and Lee (2004), who identified three main approaches to e-Learning: the macro-adaptive approach, the aptitude-treatment interaction approach, and the micro-adaptive approach. The latter of these approaches is defined as adaptations made while the user is on-task, as opposed to adaptive decisions being made after iterations of a certain task. Examples of these on-task measures are response errors, response latencies, and emotional states.

Several examples were given in the article of methods of adaptivity, and particularly important to the particular application in this paper are the methods that adapt content presentation and the learning environment. In content presentation, strategies are employed to modify the organization, format or the amount of the information presented to the user, and thus is an adaptation of content difficulty as well; while in adaptations of the learning environment, usability, accessibility, and changes to the visual appearance of the adaptive interface are the main concern.

B. *Details of the proposed system*

This paper proposed a game-like training experience inside an application developed for display in a 3D virtual space on mobile VR, or more specifically, on VR-capable Android smartphones. The key reason for the decision to develop for mobile VR instead of for sophisticated VR platforms, such as the Oculus line of devices, for example, is how cheap and easy-to-acquire headsets designed for smartphones have become. Given that the goal was to inform and educate, an accessible platform was chosen to make the proposed training application accessible to the widest range of people possible as well. It is also with this idea in mind that this paper sought to avoid the need to purchase additional controllers to use the game, so as to do away with the need for additional costs, as well as to perhaps simplify the interface.

This paper proposed that gaze-based interaction, or alternatively, gaze-based controls combined with the Action button on Google Cardboard-compatible headsets be implemented in the place of an external controller. In Kim et al.s (2017) study, they found that the most immersive and satisfying feedback system in-game were the use of a circular slider to indicate time left to select an item, and the modifying of an objects transparency to confirm that the user is indeed placing their gaze on it; the former having the consequence of a waiting time before a game object is finally selected, and the latter having the consequence of contributing to VR sickness experienced by the user. These are feedback systems that will be considered in the design of the feedback system for this game.

The proposed game sought to allow for personalized learning by adapting the learning activities according to the characteristics of the users household. This data was collected from the user by asking the user a series of questions in-game through dialogue with a non-playable character (NPC). The users choices then affected the tasks that were given to them in a training module that involves preparing their house from a typhoon, and the situations that were presented to them in another module that involved being in the middle of a typhoon. The game noted, among other characteristics, the composition of the households residents as this may affect the relevant materials that need to be prepared should a family need to evacuate. For example, the presence of members who take certain maintenance medicines would need these to be packed into a familys disaster supplies kit. These variables created minor modifications to the games narrative by adding objects or changing the objectives. A similar approach was used by Thue et al. (2007), in their PaSSAGE system which determines what events to feed the user depending on what kind of player it is able to model the user as.

The reasoning behind the choice of these variables for personalization is because disaster risk is also a matter of vulnerability, along with being a matter of a populations exposure to natural hazards. A big part of what determines a households vulnerability to disaster risk is their capacity to cope, which is defined as the strengths or resources that are used to minimize the harmful effects of a hazard–resources that may be limited by the composition of a household or by socioeconomic status (ACCORD Inc., 2012). In relation to the problem of difficulty in navigation mentioned earlier, an example of an adaptive feature presented by Hamdaoui et al. (2018) is if, for example, the game finds that a user has stood in the same spot in the virtual space for a longer time than usual. They suggest that the reason for the behavior may be that the user has either lost interest, or does not know what to do next. In the application, when it is observed that the user is not accomplishing tasks as defined by the checklist in the module, it will gently call the users attention back using clear visual or auditory cues, or by displaying graphical reminders of navigation controls and the tasks at hand.

As for the training modules themselves, the sessions were divided into 15-minute segments to minimize or avoid the effects of VR sickness, and to maximize the benefits that VR learning has over traditional methods (Kim et al., 2017). The content of the modules for practices before and during typhoons will be designed based on training modules written and made available by ACCORD Incorporated (2012) on community-based disaster risk management, disaster preparedness, contingency and risk-reduction planning, and the conducting of disaster drills in communities; and flood safety and preparedness tips published on the Susquehanna Flood Forecasting and Warning System website. Some of the scenes are interactive but not game-like (i.e. the watching of informational videos through a television screen in the house), while other scenes will take on a more game-like form that will train the user to make correct choices when given particular scenarios.

VI. CONCEPTUAL FRAMEWORK

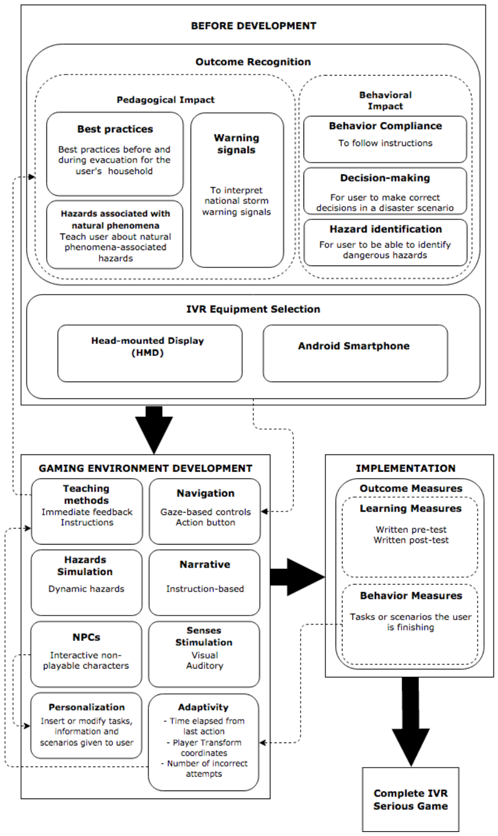

Fig. 1. The conceptual framework based on the framework created by Feng et al. for the design and implementation of IVR SGs (2018).

We chose to adopt a conceptual model based on the one designed by Feng et al. (2018) that generally describes effective design and implementation of immersive virtual reality serious games (IVR SG); more specifically, IVR SGs that train or evaluate users in building evacuation scenarios due to natural or man-made hazards. We also added, as a component under the gaming environment development phase, our personalization feature which modify two other components in the same phase, the narrative and the occurrence of interactive non-player characters (NPCs).

A) Before Development

a) Pedagogical Impact - the expected learning outcomes for this game are: (1) for the user to learn the best practices particular to their household for preparing and coping with the effects of hazards caused by typhoons and floods before and during the natural phenomena occur, (2) for the user to know and understand these hazards, and (3) how to interpret the relevant storm warning signals used on a national level.

b) Behavioral Impact - the behavioral outcome expected of the user is for the user to follow and remember the instructions taught to them by the game as they progress through the simulations.

c) IVR Equipment Selection - a head-mounted device (HMD) designed for Android smartphones is the choice for this game.

B) Gaming Environment Development

a) Teaching Methods - in the paper by Feng et al., they found that whether the teaching approach is by giving feedback (immediately or after the simulation finishes) or by providing the user with instructions in advance both produced positive learning outcomes in the papers they studied. For this game, the approach that is used is to provide the user with both instructions relating to the actual content in advance and guidance during gameplay (i.e. feedback as hints when user is inactive or is making incorrect decisions in the game) where necessary.

b) Navigation - for navigation, the game will make use of mixed gaze-based controls and the Action button found on Google Cardboard-compatible headsets to remove the need for any external controllers.

c) Hazards Simulation - there are two categories for hazard simulations: static and dynamic. Static means that the hazards exist only in the environment to incite emotion or to define or enhance environments, not to be interacted with by the user. Dynamic then, means that the hazards can be interacted with and affect the users in-game representation. For the purposes of this game, the hazards are dynamic. (Feng et al., 2018) An example for this is if the user is outside and walks into moving floodwaters, the user will find themself taken away by the waters, and then placed back at the last checkpoint with an explanation why the users previous action was incorrect.

d) Narrative - the narrative for this game is instruction-based, which means that the user is given instructions and then allowed to freely move around in the virtual environment. Being given instructions will encourage the user to remain and progress on the storyline as set by the game (Feng et al., 2018).

e) Non-playable Characters - the NPCs used in the game are interactive NPCs, and their functions are to gather data from the user using dialogue options or to present the user with a situation and an outcome to an incorrect response to that situation.

f) Senses Stimulation - given the hardware limitations, the only senses actively engaged in this game are visual and auditory.

g) Personalization - like previously mentioned, this paper desires to see the implementation of a personalization of the users experience during gameplay. The game collects data from the user about the characteristics of their household by use of dialogue options prompted by NPC and adapts to this information by inserting or modifying events given to the player throughout the game.

h) Adaptivity - for the games adaptivity features, three variables relating to the user were chosen to be tracked by the game.
   i) Time elapsed from last successful press of Action button - the games approach to adaptation using this variable is micro-adaptive—that is, it applies change to the learning environment (i.e. hints describing how to walk and select objects) when it determines a delay in response from the user.
   ii) The players in-game position (x, y, z) - this variable is used to make adaptation decisions if the user is currently on the task of assembling a supplies kit using the checklist given in the game. Similar to the first, adaptation decisions are made with this variable in mind when the game determines a delay in response from the user. When time is running out, the game attempts to adjust the difficulty of the task by rearranging the checklist to present the user with the items that are nearest to them in-game. This is also a micro-adaptive change to the learning environment.
   iii) Number of incorrect attempts - the adaptive method using this variable is to apply change to the learning environment (i.e. showing hints that suggest the correct response or inform the user that they are making incorrect choices) after determining that the user is repeatedly committing response errors. This is also a micro-adaptive approach.

C) Implementation
   a) Outcome Measures
      i) Learning measures - to measure the users knowledge acquisition, this paper uses a written pre-test and post-test exam.
      ii) Behavioral measures - to track tasks or scenarios finished for the purposes of checking for inactivity and for saving users progress.

VII. METHODOLOGY

The application was created with the aim to train citizens living in typhoon-vulnerable areas on how to deal with various scenarios that may occur should a typhoon strikes their area. The user will be put in the situation wherein a typhoon is about to and is occuring in a virtual environment. This virtual environment includes a house interior, an outdoor scene comprising of various dynamic hazards, and other interactable objects within the mentioned places. The following further details the features of the application:

A) Application
   a) Basic controls
      i) Gaze - The first basic control the user can perform in the application is gaze. The user is able to look around with the help of a reticle that can be regarded as a cursor on a computer screen. The gaze is also used to steer the user while walking.
      ii) Action button - this button is located on the HMD and is used for selecting or interacting with objects in the environment.

   b) Movement
      i) Walking - the user is able to move around the environment by means of selecting the walker tile, which is a white square tile that appears on the floor when the user looks at an angle from approximately 120 degrees to 180 degrees with respect to a vector pointing upwards along the users Y-axis.
      ii) Interacting with object - the user is able to select interactable objects in the environment by clicking the Action button once the reticle is pointing at an object. An object is interactable if the reticle dilates when it is pointing at the object. Other interactions include holding objects, placing objects on surfaces, or putting them in the bag.

   c) Interface
      i) Menu screen - once the application has loaded, the user will be greeted with a menu screen where they can start a new game, or load a previously saved game.
      ii) Modules - the application is partitioned into three portions, namely: the Introduction, Before Typhoon, and During Typhoon modules.
         1) Introduction - this module consists of a lesson on rainfall and public storm warning signals that will be shown to the user via video on a television screen. This scene occurs inside the house. After the video lesson, an NPC knocks on the users door and engages the user in a conversation. Integrated in the dialogue are questions that determine:
            a) Number of members of the household - will be used to determine how much food, water, etc. will be listed in the supplies kit checklist
            b) Number of household members who need medication - will be used to determine how many units of medicine will be listed in the supplies kit checklist
            c) Number of household members who are children - will be used to determine how many units of toys or comfort items will be listed in the supplies kit checklist; and if a scene where a child companion of the user in-game asks to play in flood water will be presented
            d) Socioeconomic self-categorization (poor or well-off) - will be used to determine whether the supplies kit checklist will include only the most necessary items, or will also include

additional convenience items

e) Possession of an LPG tank (owns or does not own) - will be used to determine the availability of an LPG tank in the house scene
f) Availability of electricity (available or unavailable) - will be used to determine the availability of a main electrical switch in the house scene (for user to virtually switch off before leaving the house)

2) Before typhoon
   a) Assembling a personalized emergency preparedness kit - the user will be provided a checklist of items, composed according to socioeconomic self-categorization and household composition, which the user will use as a guide for assembling a supplies kit, which will be useful in the event of an emergency. The user will have to search for these items in the house and put them in a bag. For added difficulty, there will be items around the house that will be interactable (therefore selectable and can be placed in the kit) but are not included in the checklist.
   After accomplishing this game, the user will be given an explanation on the purpose of the kit and the items packed in the kit.

3) During typhoon
   a) Alert on incoming typhoon - the user will be alerted about the incoming typhoon through a pop-up on the screen.
   b) Turning off electricity and shutting off LPG tank valve - if the user answered that their household possesses electricity or an LPG tank valve, this scene will direct the user to turn off the main electrical switch or shut off the LPG tank valve. In the case that these items are not available to the user, or after the user completes the task, the door will be highlighted and the user will be instructed to leave the house by selecting the door.
   c) Presentation of various hazard scenarios during evacuation and actions that user may take - The user will be made to go outside and encounter various common hazards, particularly, downed electrical poles, still floodwater of unknown depth and whether it is safe for children to play in them, and shallow but rapidly moving floodwater.

B) Application features

a) Timer - a timer will run hidden in the background which times the usage of the application. The timer shall alert the user when 15 minutes has passed, and will save the game promptly. The user will then be asked to remove the HMD and take a momentary break.

Fig. 2. The menu from the game

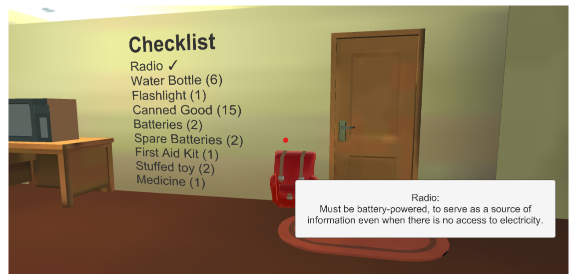

Fig. 3. Assembling a checklist in the Before Typhoon module

Fig. 4. A moving water hazard from the During Typhoon module

b) User profiles - this feature will enable the user to save their progress and resume to where they left off in the game, given that they havent finished the entire application once the 15-minute time is up. The application will create a serialized binary file and a human-readable text file in the mobile phones local storage, containing details such as which module the user has left off, objects available in the environment, and the users last position in the environment.
c) Adaptivity - the application will make use of the following variables to implement the adaptivity feature:
   i) Time elapsed from last successful press of Action button - a press of the Action button is considered successful when the outcome of the button press propels the user a step closer to completing a task. For example, a successful press in the Emergency Preparedness Kit game is a user correctly selecting an item that is included in their checklist. Selecting

the walker tile to start or stop walking is also considered a successful press. If the user has been idle and has not made any successful presses in a span of 30 seconds, it is assumed that the user must be confused or is having difficulty navigating around. Graphical hints such as arrows or highlighted objects will appear in the environment once the timer reaches past the 30-second time limit. The user is assumed to be active while walking around the virtual environment, thus, the timer will not start ticking if the user is walking.

ii) The players in-game position (x, y, z) - when running out of time (i.e., a minute before the 10-minute mark) for the Emergency Preparedness Kit game, given that the user has been selecting all the correct items in the environment (i.e. not putting unnecessary items in the kit), the checklist will be rearranged such that the items existing within a certain range from the users current in-game coordinates will be prioritized. For example, the user is in the living room, and there are items on the checklist that are located in the next room, items on the checklist that are located in the living room will be placed first on the checklist. This adjusts the difficulty for the user while maintaining the flow of the game.

iii) Number of incorrect attempts - if the user has been selecting incorrect or unnecessary items in the Emergency Preparedness Kit game or making incorrect decisions in the During Typhoon scenarios, then the user will be presented graphical and audio hints to explain and encourage the user to make the correct choices.

C) Training

a) The target respondents are Marikina residents aged 18-30 years old.
b) The respondents were asked to answer a form wherein they signed up for their preferred schedule and venue to conduct the training.
c) The location wherein training was conducted more frequently was in the Alumni Engineers Centennial Hall (AECH) building, specifically in the Service Science and Software Engineering (S3) laboratory. Other places included cafs in Marikina.
d) The respondents were made to answer the pre-test and post-test questionnaire prior to and after using the application, respectively.
e) A respondent was given a maximum of 3 tries or 45 minutes to complete the application.
f) A respondent was given a maximum of 1 hour to complete training, which includes answering the questionnaires and finishing the application.

VIII. Results and Discussion

A. Training

There were 20 respondents who partook in the training using the VR game. The tests were answered on online forms, and the total points for each test is 37. Below is the breakdown of each respondents pre-test and post-test scores, and the differences between the scores.

No.	Pre-test	Post-test	Difference
1	31	35	+4
2	27	30	+3
3	33	33	0
4	34	35	+1
5	34	34	0
6	24	31	+7
7	28	30	+2
8	20	33	+13
9	29	32	+3
10	33	35	+2
11	35	36	+1
12	24	26	+2
13	27	34	+7
14	32	35	+3
15	31	33	+2
16	30	33	+3
17	24	28	+4
18	30	33	+3
19	29	34	+5
20	32	34	+2

TABLE I

The pre- and post-test scores of the 20 respondents, as well as the difference between them.

The data was analyzed using the Wilcoxon signed-rank test to compare the two sets of scores that come from the same respondents, before and after playing the game. The reason for this choice of test is due to non-normal distribution of data due to the presence of an outlier.

Ranks

		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	0[a]	.00	.00
	Positive Ranks	18[b]	9.50	171.00
	Ties	2[c]		
	Total	20		

a. POST < PRE
b. POST > PRE
c. POST = PRE

Fig. 5. Wilcoxon S-R test rank table produced from the pre- and post-test scores.

Looking at Table 1, it can be seen that the differences between the respondents pre- and post-test scores were either 0 (meaning the scores on both tests are similar, and that these differences are to be excluded from the computation of the sums), or positive (meaning that the post-test score is greater than the pre-test score). This same result can also be seen reflected in Fig. 5. Of the two sums, the sum of the positive ranks is obviously considerably greater.

In Fig. 6, the output of the Wilcoxon S-R test indicated that the post-test scores achieved by the respondents after playing

Test Statistics[a]

	POST - PRE
Z	-3.743[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Fig. 6. Final Test Statistics table produced by the Wilcoxon S-R test.

the VR game were statistically significantly higher than the pre-test scores before playing the VR game Z = -3.743, p = 0.000 (0.000182).

B. User feedback

Although user acceptance of the VR game was not evaluated as it is beyond the scope of this paper, the researchers were however able to receive some user feedback from the respondents. It was found that of the 20 respondents, 12 reported feelings of VR sickness. According to 4 of those 12 respondents, they attributed their nausea to the constant movement done in the virtual environment as they brought supplies scattered around the house one-by-one to a stationary backpack in the Before Typhoon module. Another respondent cited the lag they experienced as they played the VR game for their nausea, while another felt that the duration of use was too long.

For the controls, 10% of the 20 respondents found that the controls were not intuitive, and 30% found difficulty using the controls. Many found the walking mechanic (pressing on the Action button while looking walker tile to start or stop walking) of the VR game difficult to use. One respondent even suggested future compatibility with a controller. Another common problem the respondents had was with the previously mentioned mechanic in the Before Typhoon module that many felt was time-consuming and made them prone to nausea. Other problems cited by the respondents were the readability of text inside the game, and the hints/guides not being frequent or available enough. Some respondents also suggested that there be more content featured in the game.

IX. CONCLUSION

This paper detailed a preliminary design for an adaptive VR game for training members of a community to identify the best practices for their household should they find themselves in typhoon or flood situations.

The game personalized its content by collecting information from the user using questions that ask them about the number of people in their household, the number of people who are children or need medication, and whether they have access to LPG tanks or electricity. These personalizations of content were found in the quantities of certain items that the user was tasked to collect, and particular tasks that were given to the user (e.g. the task of shutting off electrical power or LPG tank valves if the user says that they have access to either).

Adaptive features were also implemented in the game. By tracking the users inactivity or the number of incorrect attempts a user makes for a particular task, the game adapted to a users behavior by showing hints that aimed to help the user proceed. In the Before Typhoon module where the user has to assemble a supplies kit, the game also adapted the difficulty according to the users in-game position by rearranging the supplies kit checklist to show the items closest to the user, once the timer for the session is close to running out.

Finally, the Wilcoxon S-R test indicated that the post-test scores achieved by the respondents after playing the game were statistically significantly higher than the pre-test scores they achieved before playing the game, suggesting an improvement in knowledge of the content featured inside the game.

X. RECOMMENDATIONS

Following the feedback received on the game as presented in this paper, the researchers once again propose a design that takes those into consideration and adds it to the current version of the game, serving as a recommendation of sorts for other researchers interested in undertaking similar projects.

A. Application

A) Basic controls and movement - in addition to the original gaze-based and Action button implemented in the current version of the game, pursuing compatibility with external controllers (such as those that connect to the smartphone via Bluetooth) may be worth looking into. Many of the respondents were not accustomed to the use of VR headsets, and may have benefited from some other, more common way of navigating inside the virtual environment. One suggestion for the walking mechanism is an alternative to make the user stop walking. Instead of having to click the tile again to stop walking, looking or bumping into the tile could make the user stop walking.

B) Interface - In accomplishing the task of assembling a supplies kit, respondents found it difficult in the current version of the game to have to select objects around the house one-by-one and take the objects to the backpack to mark it off the checklist. One possible way of resolving this problem would be to have the backpack move to near where the player is, or to instead implement the mechanic so that selecting an object directly sends it to the users inventory.

B. Application Features

A) Point system, leaderboard - point system and leaderboard mechanics are suggested here because these mechanics could potentially increase the level of gamification of the content presented, and could also potentially increase the users engagement with the material.

B) Adaptivity - adaptivity can be further improved by having the system track the performance of the user as they play the game. The inactivity timer threshold and hints provided to the user could be adjusted accordingly in real-time as the user is exploring in-game. The inactivity timer duration could be shortened if the system finds that the user navigates easily or completes tasks quickly, or lengthened if the system detects otherwise. An example of hint that can be implemented is the highlighting of the objects in the Before Typhoon module if the system detects that the user has passed by the object several times but hasnt tried to grab or select the object. Auditory hints could also be considered.

C) Personalization - more opportunities for content personalization in-game can be explored should one choose to take into account varying areas of residence, as well as the also varying levels of risk that are associated with different areas.

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