AR Wave

In Partial Fulfillment of the Requirements for the Degree
Master of Science in Information Management and Systems

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I. Acknowledgements

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II. Abstract

Earthquake preparedness is an important issue at UC Berkeley since its campus lays on the Hayward Fault. In this project, we explore the level of preparedness among students at UC Berkeley through surveys and interviews. We then, design a mobile application that uses augmented reality (AR) technology to mitigate the weaknesses in earthquake preparedness we found in our research. Through three iterations of design and development and usability testing, we explore the possibility of using AR technology to create vivid and personalized earthquake readiness training for students.

Keywords

Augmented Reality (AR), earthquake, earthquake preparedness

III. Introduction

United States Geological Survey (USGS) estimates the probability of a large earthquake (>=6.7 magnitude) occuring in the San Francisco Bay area at 67% before 2032 (When Will It Happen Again). However, since there has not been a deadly (magnitude of 8 or higher) earthquake for many decades, people go on with their daily lives unaware of this threat (1999, The Third California Earthquake Rupture Forecast). Education about earthquake preparedness is especially important as it is difficult to predict when earthquakes will happen. This unpredictability leaves citizens in earthquake-prone areas highly vulnerable. With AR Wave, we would like to help the Berkeley community prepare for disaster and increase awareness about what to do in the event of an earthquake. In the long run, this will help reduce casualties from earthquakes and the subsequent emotional turmoil for affected families and communities.

UC Berkeley serves a diverse population of students. In 2017, 4,490 students from the freshman class were from out-of-state. There are also 1,362 international students in the freshman class (UC Berkeley Fall Enrollment Data). This means that up to 40% of the freshman class might not have ever received earthquake drill training. Students from regions that are not prone to earthquakes not only lack knowledge of how to properly prepare for these shocking disasters but also haven't developed the understanding of how far-reaching the consequences of an earthquake can be. Earthquakes can result in isolation, lack of clean water, and damaged communication lines -- all situations that most students have never contemplated. Although the Office of Emergency Management at UC Berkeley offers a variety of educational resources to prepare students for earthquakes, the lack of urgency and knowledge about earthquakes make it easy for students to miss these resources. Although there is the Great California ShakeOut drill every year, participation is not mandatory and the participation rate is not clearly checked. The earthquake knowledge gap is especially dangerous for people who are new to California.

IV. Project Goals

The goal of this capstone project is to deal with some of the issues of misinformation and indifference towards earthquake preparedness by using mobile Augmented Reality (AR) technology to create personalized, vivid earthquake drill experiences on users' smartphones. Through the training provided by the mobile app, we hypothesize that the local community will become more aware of our vulnerability to earthquakes and more encouraged to take preventative actions. Ultimately, through the iterative development of our application and partnerships with emergency response organizations, we hope to generalize our app for other earthquake-prone regions as well and break down commonly held misconceptions about earthquake preparation and survival protocols.

V. Research

Study results from Kapucu et al. show that disaster preparedness is positively correlated with training and exercises (Kapucu et al., 2016). This means that students should all receive earthquake drill training to maximize their readiness for the next big earthquake, no matter when or where it strikes.

According to the U.S. Bureau of Labor Statistics, American Time Use Survey 2016 results, employed people worked on average 7.99 hours during the days they worked (U.S. Bureau of Labor Statistics). An earthquake could occur anytime during these 7.99 hours at work, or at home, or even on the way to and from work. Thus people need to be aware of earthquake safety protocols in any environment.

Currently, many students ignore the fact that they should be ready for an earthquake at any time or place. According to Federal Emergency Management Agency (FEMA), preparedness involves detailed action plans related to before, during and even after earthquakes (What Is Disaster Assistance).

In order to learn more about current solutions for earthquake preparedness (such as earthquake drills) and their pain points, we conducted a face-to-face interview with the Office of Emergency Management (OEM), UC Berkeley to understand the following: 1) current pain points of enforcing an annual earthquake drill; 2) possible misconceptions among students; 3) current student groups and organizations working on earthquake preparedness; 4) current outreach and training formats and possible features to consider in our application development, etc.

We discovered the following results from our interview:

1) The Great California ShakeOut Drill is conducted once a year, but it's optional. Thus, some students inevitably miss the drill.
2) The practice drills and resources are not impacting enough students. For example, only around 10% of fraternities / sororities on campus received earthquake drill training.
3) Current emergency preparedness apps provide only just-in-time training, not before and after training. It is also difficult to get students to download the app. Even when students do download OEM's current app, they will be faced with lists of information and subsequent information overload.
4) Though a majority of the students already know "drop, cover, hold-on" is the appropriate action to take during earthquakes as a general guidance, many of them don't know the accurate context related to each action, leading to various misconceptions. Students aren't aware that even if there isn't a table nearby, they should "drop, cover, hold-on".
5) Many students are unaware that they are not expected to run outside during an earthquake, and they don't know the evacuation routes of most buildings either.
6) Furniture in many locations are not secured properly to withstand an earthquake.

From this interview, we determined that the target users of our app would be UC Berkeley students and that we needed to create urgency to incentivize students to learn more about earthquake safety.

As part of our research, we have looked into clearing up existing misconceptions about earthquake preparation and safety. We utilized the Federal Emergency Management Agency (FEMA) and the United States Geological Survey (USGS) as authoritative and primary sources of information in our research and our application development. Using the AR Wave app, our goal is to disseminate the recommended earthquake safety actions in an innovative and interactive way in order to reduce accidental injury during the next earthquake.

VI. Preliminary Surveys

Goals

To help us better understand the current level of preparedness among students at UC Berkeley, we decided to conduct a survey as surveys can reach a large number of students and elicit structured feedback quickly. This would allow us to determine what the earthquake preparedness needs of the student body currently are and where to begin designing solutions to meet those needs.

Hypothesis

In this survey, we would like to explore the following hypotheses:

- Students at UC Berkeley, both international and domestic, are not well-prepared for earthquakes.
- Current drills do not help students prepare well for earthquakes.
- Situational factors exist that affect the level of preparedness among students.

Methods

We created a survey using Google Forms and distributed the link to a popular Facebook group for UC Berkeley students ("Free & For Sale"). We also posted flyers with a QR code and link to the survey around campus. We ultimately received 170 responses.

Findings

Demographics

Since our target users are students, among the 170 responses we received, we had 156 valid responses from UC Berkeley students. First, we will check the demographics of this dataset to make sure it is representative of the students at UC Berkeley.

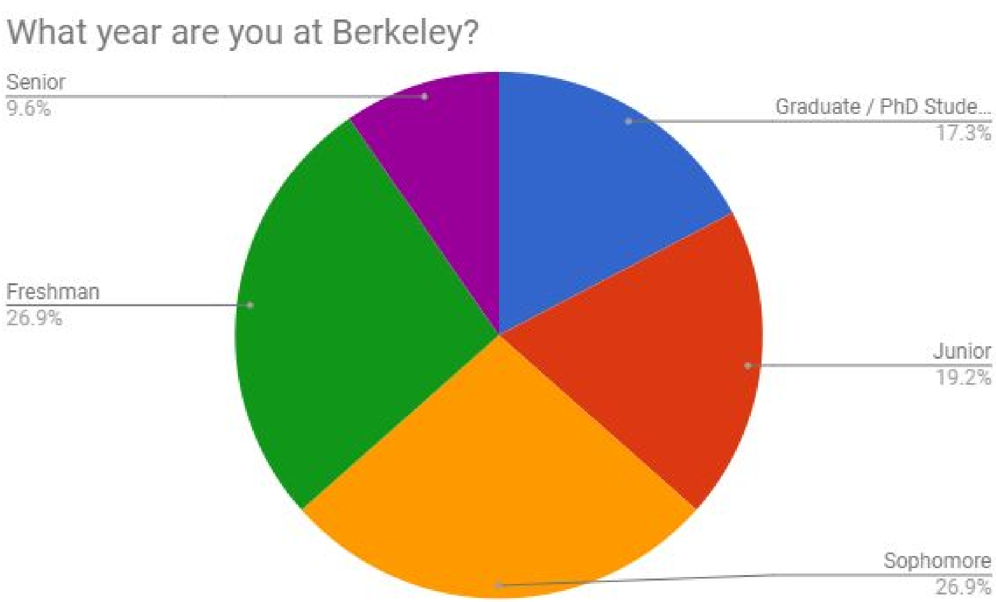

Figure 1. The distribution of the students' year

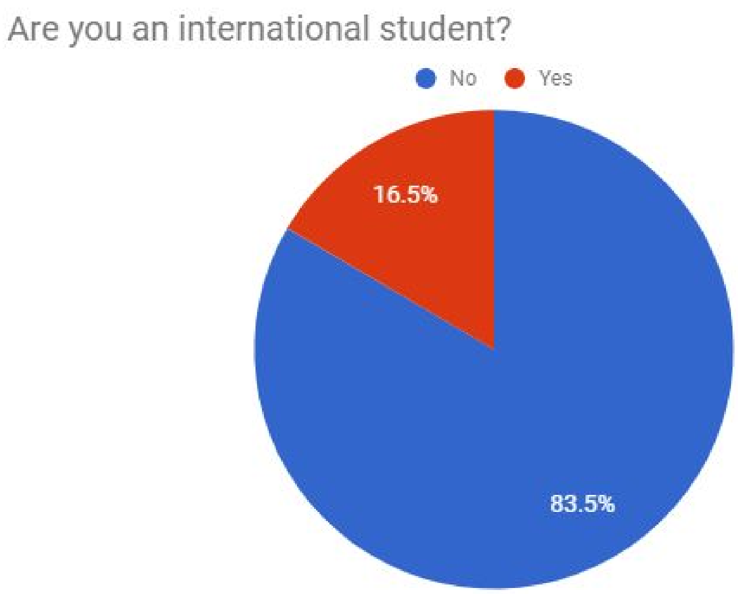

Figure 2. The percentage of the students' origin matches the overall percentage at Berkeley

Within our survey data, ever class year is represented. Furthermore, 16.5% of participants are international students, which is close to the total percentage of UC Berkeley students that are international students. According to the UC Berkeley Office of Planning and Management, 16.7% of the student body is international. Therefore, we believe our survey results are a representative sample of UC Berkeley students in assessing their level of earthquake preparedness.

Hypothesis 1: Are students prepared?

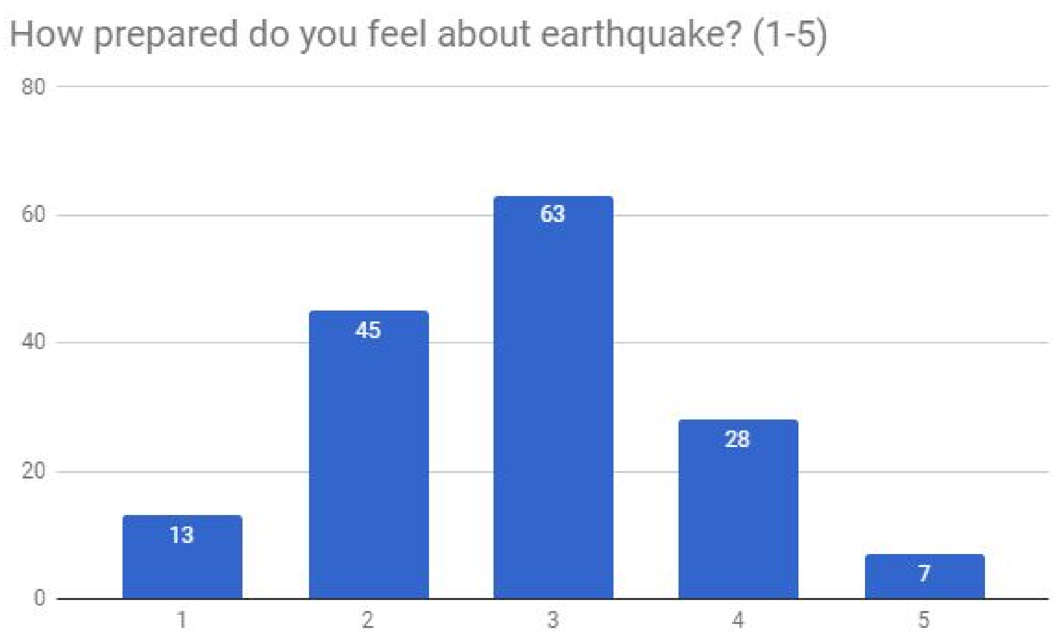

Figure 3. The distribution of students' preparedness

In this survey, we asked the participants "How prepared do you feel about an earthquake?" to assess their own perception of readiness. The average score was a 2.81. Moreover, when we check the international students and domestic students respectively, we found the average score of international students (2.61) is lower than the average score of domestic students (2.85). We can conclude that almost half of our participants feel inadequately prepared for an earthquake, especially among international students.

In the following question, "What are the recommended safety actions?", participants were required to elaborate on what actions they would take during an earthquake. We wanted to validate whether students' perceptions matched their actual level of preparedness. To our surprise, among students who rated their level of preparedness as a 4 or a 5, we found there is a deep misconception. More than 86% of these students mentioned a doorway in their responses. Earthquake experts indicate that hiding under a doorway should not be one's first reaction to an earthquake and is a common misconception.

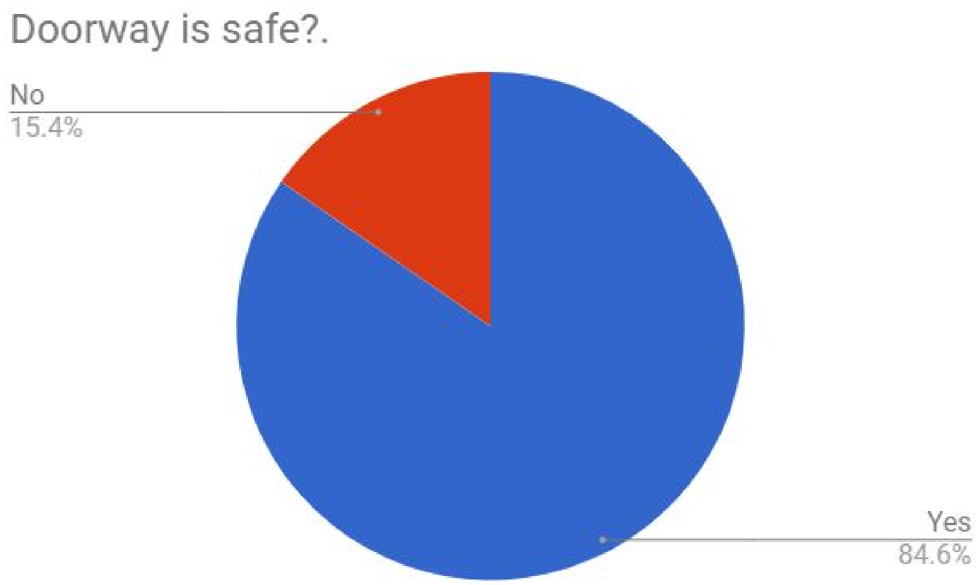

Figure 4. Students' understanding of the safety of doorway

These survey results indicate that the level of preparedness at UC Berkeley is inadequate.

Hypothesis 2: Do drills help?

Since UC Berkeley and many high schools in California provide earthquake drills, we would like to see the actual impact of these drills.

To begin with, we checked whether students who have participated in more drills feel more prepared. When comparing the responses to "How many times have you participated in an earthquake drill?” to the responses to “How prepared do you feel about an earthquake?”, we see that the number of drills does have a positive impact on one’s confidence in earthquake preparedness. In the graph below, there is an increase in confidence from 2.17 (no drills) to 3.15 (more than three drills).

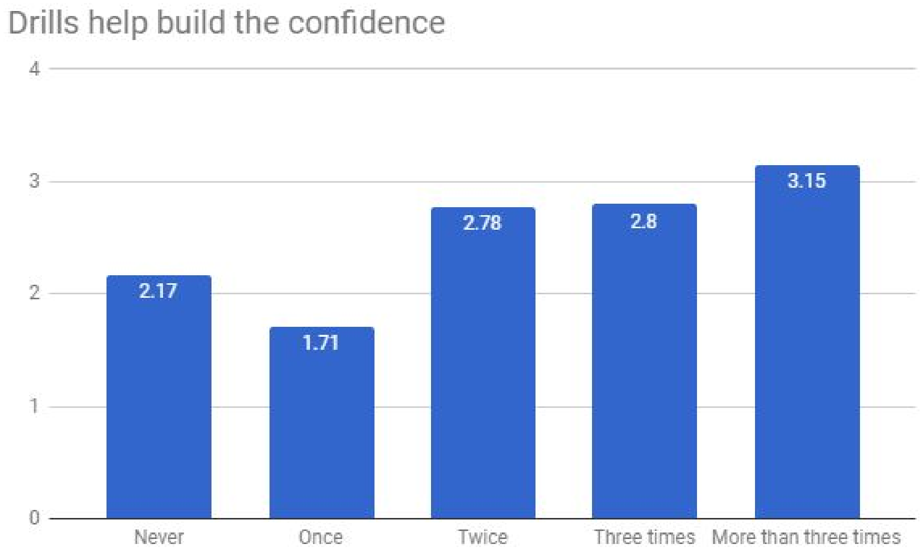

Figure 5. Drills make student think they are prepared

After finding a misconception in our previous survey question results, we wanted to explore whether drills eliminated that misinformation. Among the respondents who have participated in more than three earthquake drills, one out of three students mentioned a doorway in their open-ended responses. Out of these students, only two mentioned that doorways are an unsafe place to hide during an earthquake. This means 93% of them still hold the misconception that doorways are safe after having received earthquake drills.

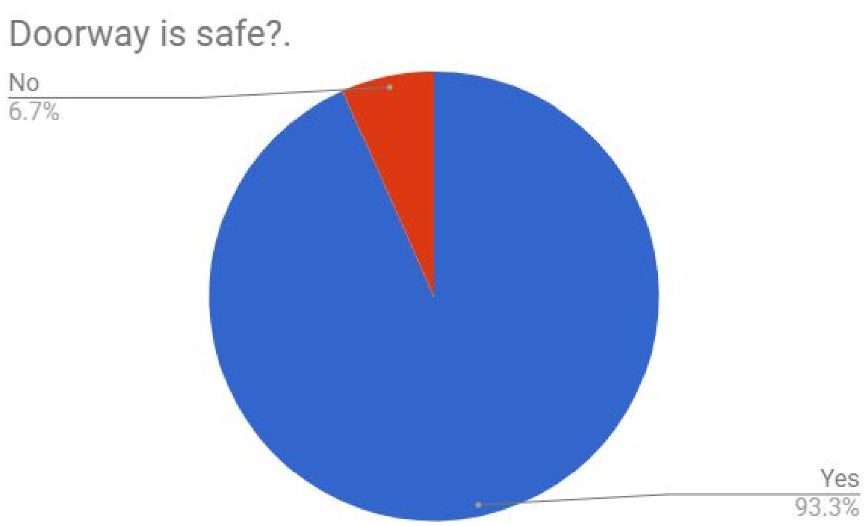

Figure 6: Even after having taken three drills, more than 90% students think doorway is safe

Thus, drills still could help student to establish their confidence to prepare for the earthquake. But it remain doubt whether it could help them to be fully prepared.

Hypothesis 3: Students are prepared in any situation?

Finally, we would like to check whether students are prepared for an earthquake in all situations or all places. For the question, “If an earthquake happened right now, at which of these places would you have trouble figuring out what to do?”, we found that students felt most unsure of how to react while using public transportation. However, we also found that more than one-third of students don’t think they are prepared for an earthquake at home either. This is verified by another question in our survey in which we found that more than 52% of students do not secure any furniture that may fall or cause danger during an earthquake.

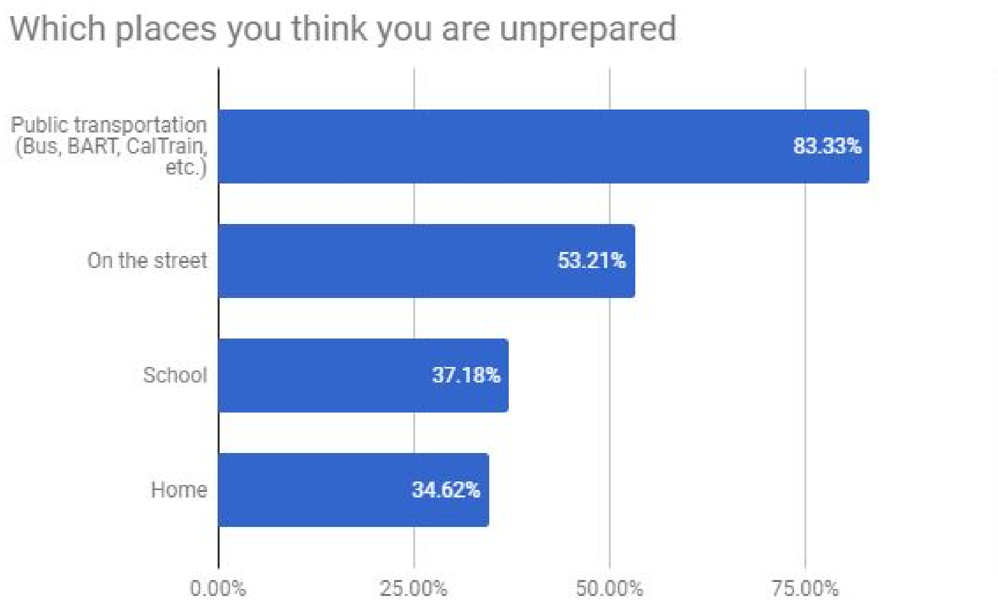

Figure 7. The places students are not prepared

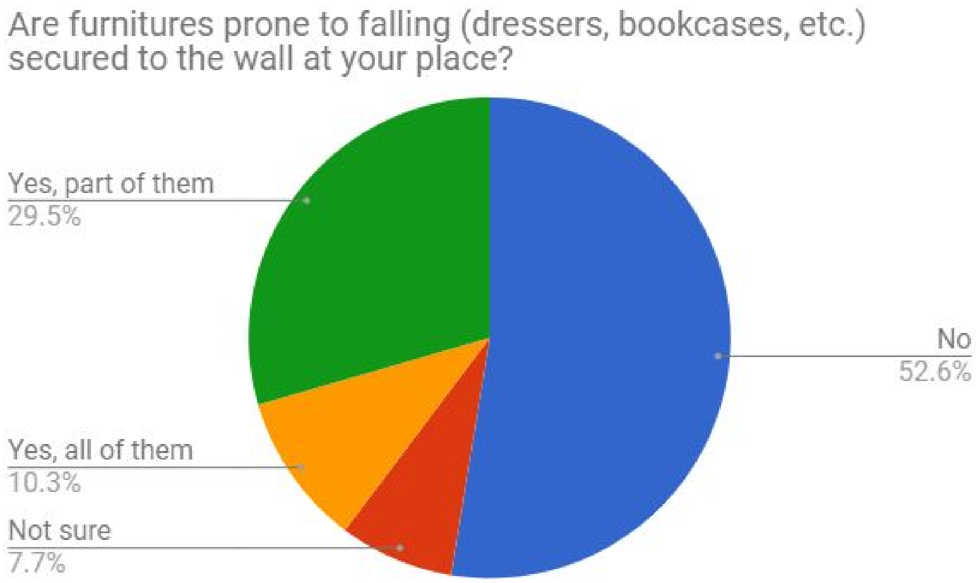

Figure 8. More than half students does not secure furnitures

Therefore, students are not prepared to handle an earthquake in all situations.

Conclusion

All of our hypotheses were validated by our survey results:

- Students in UC Berkeley are not well-prepared for earthquakes. Even those who subjectively think they are prepared are actually not.
- Current drills help students gain confidence but do not necessarily improve their earthquake preparedness.
- Students have trouble preparing for earthquakes in different situations.

The results of this survey helped us narrow down the scope of our app:

- It should provide accurate and up-to-date earthquake guidance.
- It should provide information on what to do in diverse places and situations.
- It should address the downside of current earthquake drills.

VII. Preliminary Interviews

Goals

After learning that the level of earthquake preparedness among students varies and that many students cannot recall “drop, cover, hold-on”, we decided to conduct interviews to better understand the root causes of earthquake unpreparedness and see which current methods are working.

Methods

We used a screening survey to recruit participants for our interviews. This screening survey was shared among the Free & For Sale Facebook group. The screening survey included questions about where the student grew up and what year in school they were so that we could choose students with different backgrounds. From the screening survey, we were able to recruit ten current UC Berkeley students.

We used a semi-structured interview format to make sure that our specific interview objectives were accomplished and that each participant could express their diverse experiences with earthquake training. We also wanted to be sure that we didn't miss any visual cues or demonstrations of earthquake knowledge, so we decided to conduct our interviews in-person and on campus. Our interview was organized into four main sections: student experience with current solutions, student level of preparedness, confusions, and awareness of the possibility for earthquakes.

Findings

1) The interviewees from California were very knowledgeable about earthquakes. They had received trainings from schools, which could be dated back to elementary schools. They were generally very aware of the danger of earthquakes.
2) Middle and high school drill practices in California focused on how to react during and after earthquakes, not on how to secure furniture and surroundings before an earthquake.
3) Out-of-state and international interviewees generally felt confused and unclear about what to do when an earthquake happens. Although they had heard about earthquakes, they couldn't picture one happening.
4) When asked what they would do if an earthquake was happening, all out-of-state and international interviewees responded that they would run away from the buildings or even outside. Some of the interviewees from California responded that they would drop, cover and hold on.
5) Most of the interviewees didn't have an emergency kit ready and didn't know what exactly should be included in the emergency kit.
6) The interviewees who had received extra trainings actually secured their surroundings after the trainings.

From our interviews, we learned that students who didn't grow up in earthquake-prone regions might have significantly less earthquake preparedness knowledge than their peers. Thus, we decided to focus our efforts on students who haven't received earthquake training in the past and reinforce the “drop, cover, hold-on” protocol for students who might be misinformed.

VIII. Ideation

From our preliminary research, surveys, and interviews we decided on our primary goal -- to increase the awareness of and preparedness for earthquakes among UC Berkeley students. To achieve this goal, we wanted to create practice drills for what to do before, during, and after an earthquake. We also wanted to impose repetition on our users until “drop, cover, hold-on” becomes instinctive. Finally, we wanted to use a more attractive outreach method and offer accessibility to trainings in any location.

In order to clear the current misconceptions, we divided the safety actions into three parts:

1) Before earthquake: safety actions would focus on securing furnitures properly.
2) During earthquake: safety actions would focus on practicing “drop, cover, hold-on” safety procedures under different scenarios, involving various levels of complexity.
3) After earthquake: safety actions would focus on quickly figuring out the evacuation routes.

During the ideation process, we came up with different approaches and features and narrowed those down to two important features to better address the above problems. We decided to address the problems using a mobile app because it is more portable and attractive than traditional ways of drill practice; we also decided to utilize Augmented Reality (AR) technology as a method to address the problems because it is more accessible than Virtual Reality (VR) technology, more vivid than traditional media and more applicable to customized surroundings than other media.

Mobile App as a Way of Drill Practice

Considering the target users being young, full-time students, who are characterized with a mobile mentality and think highly of portability, we decided to address the problems with a mobile app. Traditional earthquake drills usually require in-person group participation either in the classroom or workplace, ignoring one of the most frequently visited locations -- home. The route commuting between work and home is also not considered in current trainings. During periodic drill practice, the high ratio of students to instructor also make it hard for the students to get clear instruction and avoid misconceptions. It is also hard for students to re-practice by themselves. Thus, a mobile app would be an appropriate way to convey the accurate guidance and make re-practicing hassle-free. We hypothesize that the increased ability to practice will lead to our goal of making “drop, cover, hold-on” instinctive.

Augmented Reality (AR) as a Medium

Augmented Reality (AR) is an emerging human computer interaction technology that may improve the engagement of users. Current earthquake preparedness training often uses text and video media to send out the training information. However, students always skip this kind of training because the information is plain and is often too long and boring. But with AR, we believe that the new and more vivid interaction will greatly attract more students' attention compared to traditional media. It can also provide a fun and hands on training experience through game-oriented practice, thus increasing the effect of training. Virtual reality, on the other hand, is only accessible to people who own the proper equipment. AR is more flexible and accessible. Students can use the AR application to learn earthquake preparedness knowledge at anytime and any place with hands-on learning, instead of sitting in a fixed place and wearing a big headset with VR. More importantly, users can easily set up personalized surroundings for customized drill practice, such as in the bedroom, classroom, workplace, etc. AR allows users to experience vivid and personalized earthquake training.

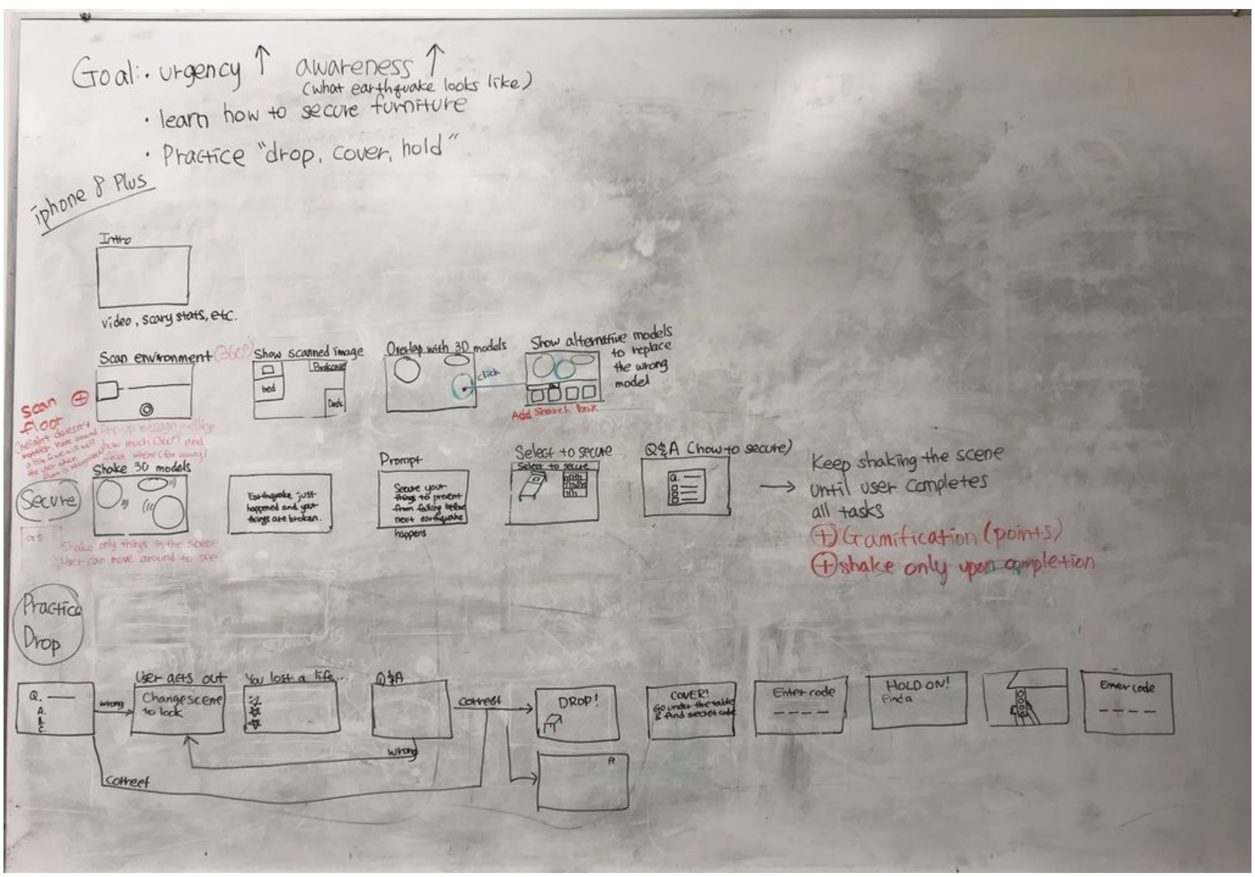

Figure 9. Application workflow Ideation

IX. Iteration I

Goals

To test our idea and explore other possible methods that might work better, we decided to make a paper prototype for a fast-and-dirty validation. The paper prototype consisted of two main features: 1. Practice drill and 2. Secure furniture.

The “Practice drill” part was a question and answer type of exercise where the user is asked tricky questions about what to do in certain situations. These situational scenarios were devised to address the common misconceptions students have as evidenced in surveys and interviews.

The “Secure furniture” part was an AR prototype exercise where the user scans a room and the app would recognize furnitures and other objects that might need to be secured in that given environment.

Specific research questions we had were:

- Does the user understand the seriousness of earthquakes and feel the need to prepare/train for it?
- What is the best way to help the user secure his/her environment?
- What is the best way to help the user learn “drop-cover-hold on”?

Methods

For a fast validation of our idea, we create a paper prototype and made it clickable on the Marvel app. We then recruited five users to conduct a usability test. The test consisted of three parts: 1) pre-test Q&A to learn about users’ experience with earthquakes and knowledge in earthquake preparedness, 2) tasks given to users -- go through “Practice drill” and “Secure furniture” quizzes, and 3) post-test Q&A to learn about users’ experience with the prototype.

Findings

From the usability test, we were able to derive a great deal of valuable information and gained ideas about how to improve our app, The key lessons were the following:

- All five participants elicited, at one point or another, their mental framework about earthquake: “What do I before, during, and after an earthquake?”. Some participants were confused whether they should secure their furniture during an earthquake or beforehand
- Although the questions in “Practice drill” part was tricky enough to have the participants interested, it also tended to confuse them. Providing them with straightforward guidance would be important

- Addressing the misconceptions proved very useful and the participants expressed high level of willingness to learn

X. Iteration II

Goals

For our second iteration of AR Wave, we wanted to fix the features and activities that caused confusion among our users during our paper prototype usability testing. Namely, we wanted to guide our users in a more structured way and prevent users from making mistakes. We also wanted to develop the augmented reality enough to test how users would interact with the technology and see whether it enhanced their learning. To do so, we made such changes and conducted a usability test to validate.

Design

App Architecture

The biggest changes we implemented were in app architecture. Based on our findings, we decided to utilize users' mental framework and adopt it into our app: what to do "before", "during", and "after" an earthquake.

Figure 10. App architecture: before, during, and after

Before section:

This section was the same as the paper prototype's "Secure furniture" section, but re-named. Like the previous iteration, the app recognized what items need to be secured once the user scans one's environment. AR objects popped up to represent the items to be addressed, then the user was asked to click on each of them to solve a quiz on how to secure that item.

During section:

"During" was the new title for what was previously called "Practice drill" in the paper prototype. Unlike the "Before" section, we made a lot of changes in this part. We removed the quiz aspect of the app and brought in a step-by-step drill guide. The guide consisted of four drills in four different situations in order to directly address the common misconceptions users revealed through our survey and interviews: 1) the regular "drop, cover, hold-on", 2) a scenario without a table, 3) a scenario where a table is far away, and 4) a scenario where other people are running outside or running to stand under a doorway. Based on the levels of complexity, we then re-organized these four scenarios into the following:

- Basic: 2) without a table
- Intermediate: 1) regular "drop, cover, hold-on"
- Advanced: 3) table is far away and 4) people are running

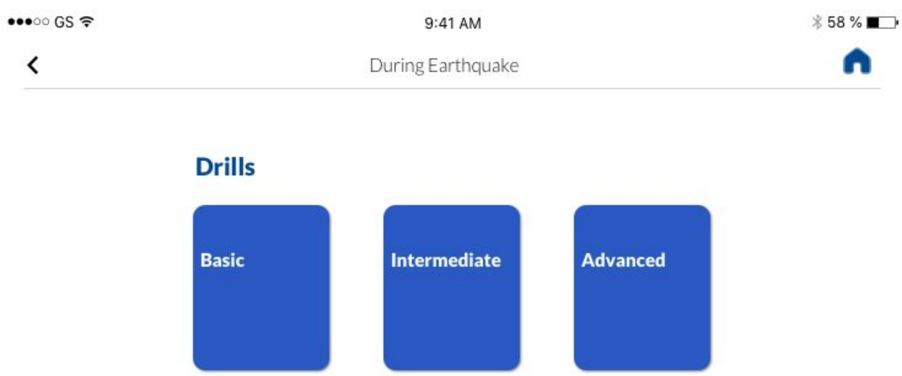

Figure 11. Four drills re-organized into three levels: basic, intermediate, and advanced

For each, the user was asked to physically follow along the drill. Although these were four different scenarios, the main concept of "drop, cover, hold-on" was the same for all, except "hold-on" might be omitted if a table does not exist or is far away. Therefore, the flow of the app was designed to promote repetition of the standard drill sequence, helping the user's body learn and memorize the action so one can instinctively react to an earthquake without thinking too much. This was critical as research showed that a big earthquake brings panic and leaves no times to think. In most cases, mob mentality is put in place. One person starts running and everyone else follows (2016, Courtney et al.). Our interviews also revealed that, even though one had received earthquake trainings, not a lot of people follow the recommended safety action because of lack of practice, conflicting drill instructions, and, again, mob mentality. Thus, we made a strategic decision to provide four differences learning points for users to repeat “drop, cover, hold-on” to improve memorability.

After section:

This is a section that we plan to implement in the future. This section will provide exit route on users phone in partnership with businesses and organizations.

Design Concept

Because a lot of users were told different safety actions (i.e. stand under a doorway, stand in the corner of the room, etc.) in the past, users who already have a concept of what to do in their minds, whether or not that is correct, were obstinate to accept new, corrected information. To overcome this hurdle, we used the color blue to add a sense of authority to the app. A hint of yellow color was combined to lesson the boredom of repeated contents (“drop, cover, hold-on”) and orange-red was added to indicate any errors or warnings.

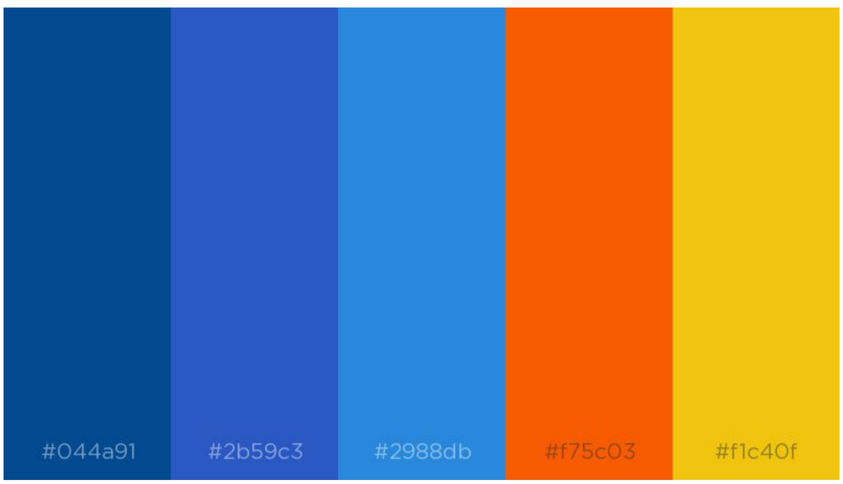

Figure 11. AR Wave color palette

The main instructions of each step of the drill was in large fonts ina strong color placed on the upper left side to easily capture users’ attention. This bold design was intended to increase readability as users need to hold the phone in one hand while taking certain actions like dropping to the floor and crawling under an AR table. The strong hierarchy enabled clear communication even when users are glancing at the phone while moving around.

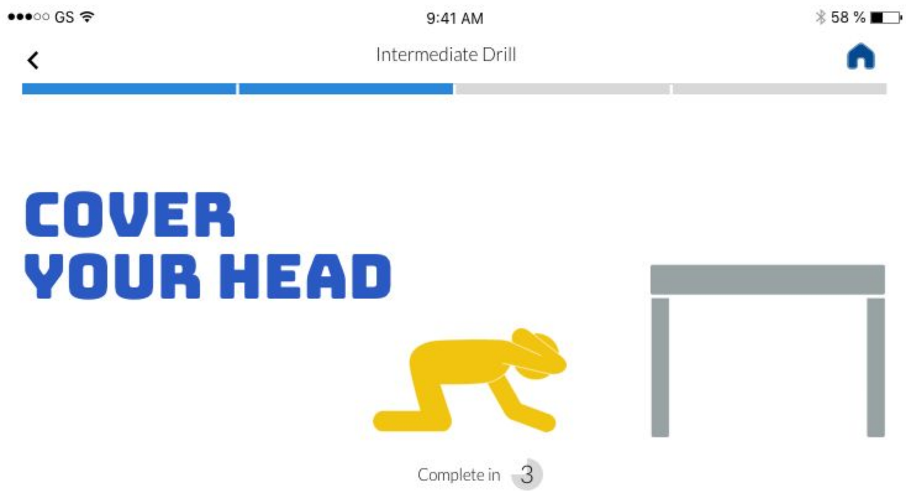

Figure 12. Clear instructions using hierarchy and layout

Development

Augmented Reality

For this iteration we also developed an AR application with Apple's ARKit framework rather than using only the prototyping tool, Invision.

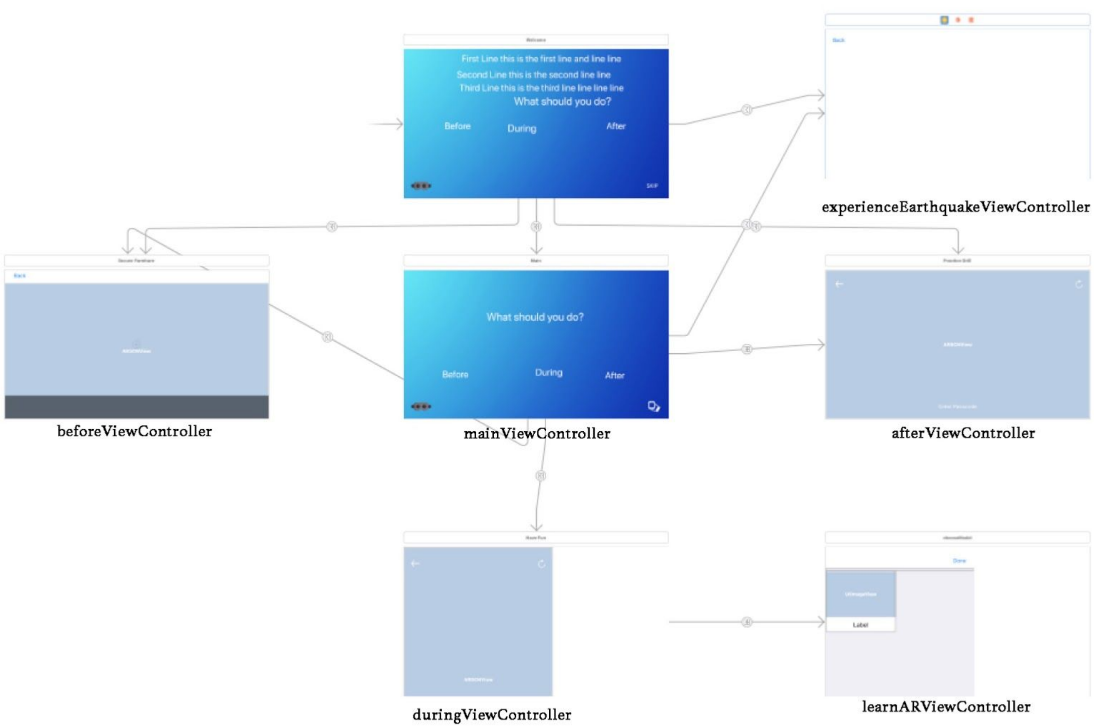

Figure 13. App Workflow

The above diagram depicted the the workflow of the development. There are mainly four viewControllers, mainViewController beforeViewController, duringViewController, and afterViewController. The mainViewController is the entry of the application, which showed the guidance information of this app. The beforeViewController was the view controller of securing furniture; the duringViewController was the view controller to practice the earthquake drill; the afterViewController was the view controller of actions after the earthquake. Besides those four view controllers, we also added two other view controllers, experienceEarthquakeViewController and learnARViewController. The experienceEarthquakeViewController enabled users to experience a real earthquake by seeing a 360 video with a cardboard virtual reality device. The learnARViewController gave the users opportunities to learn interactions about Augmented Reality technology. For the current iteration, we mainly focused on developing the during earthquake part of practicing earthquake drill.

The earthquake drill practice can be separated into three steps: drop, cover, hold-on. The development also followed those three procedures. It could also be divided into three steps: detecting a horizontal plane, placing a virtual table, and find passcode under the table.

1) Detecting a horizontal plane

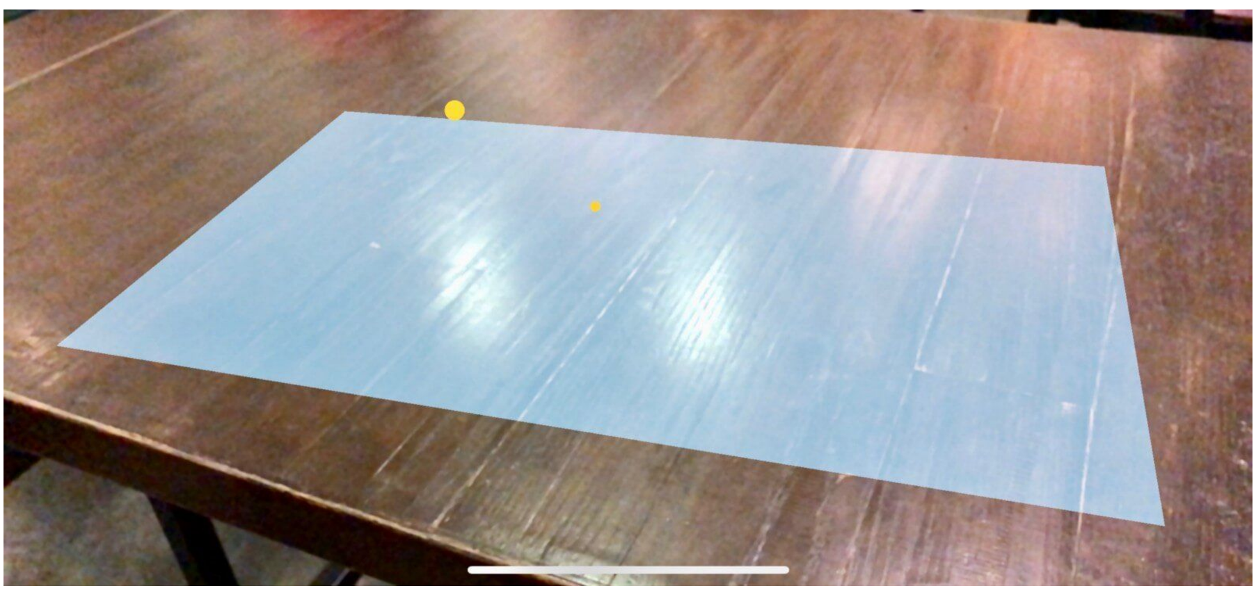

Figure 14. Detecting and visualizing a flat surface

In order to enable horizontal plane detection, we needed to enable the settings in AR configuration,

configuration.planeDetection = .horizontal

By setting the planeDetection property of ARWorldTrackingConfiguration to .horizontal, this told ARKit to look for any horizontal plane. Once ARKit detects a horizontal plane, the horizontal plane will be added into sceneView's session.

In order to detect the horizontal plane, we adopted the ARSCNViewDelegate protocol. Instead of extending the ViewController class, we implemented the renderer(_:didAdd: for:) method. This protocol method got called every time scene view's session has a new ARAnchor added.

After we got notified every time a new ARAnchor is being added onto sceneView, we add a 2D plane to visualize the detected plane. The logic to visualize the plane is,

- Unwrapped the anchor argument as ARPlaneAnchor to gather all the information about the real world flat surface.
- Created an SCNPlane to visualize the ARPlaneAnchor. The SCNPlane was a rectangular one-sided plane geometry. We took the unwrapped ARPlaneAnchor extent's x and z properties and used them to create an SCNPlane.
- Initialized a SCNNode with the SCNPlane geometry.
- Initialized x, y, and z constants to represent the planeAnchor's center x, y, and z position.
- Added the planeNode as the child node onto the newly added SceneKit node.

2) Placing a virtual table

Figure 15. Adding a virtual table

After detecting and visualizing the horizontal plane, a table was automatically added on the plane. The way we added the table automatically was almost the same as visualizing the horizontal plane. In rederer(didAdd node) method after adding the plane node, we created and loaded a table node, and added it to the sceneView.

The first two steps set up the earthquake drill environment. When a user clicked practice the drill button, and moved the carema across the floor, the tale would be placed besides the user on the plane for users to practice the AR drill.

3) Find passcode under table

Figure 16. Finding a passcode

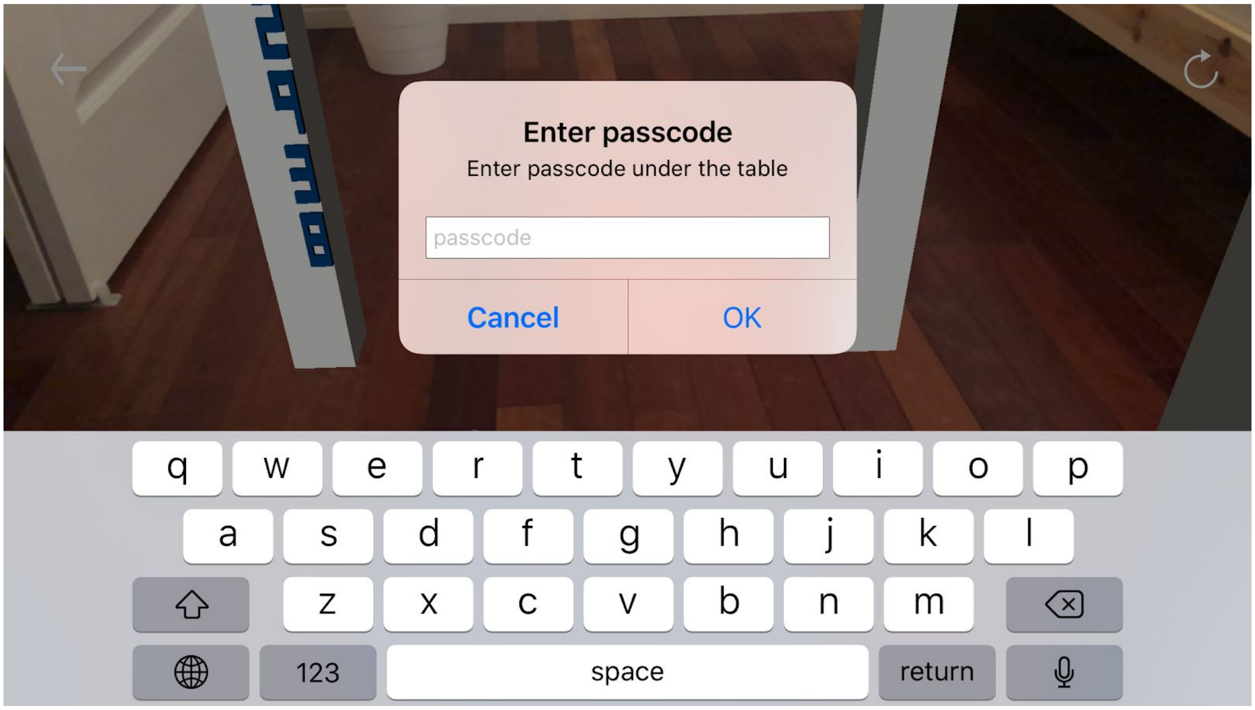

Figure 17. Entering passcode

The main actions of drill practice were “drop, cover, hold-on”. In order to let the users to drop physically, we added a passcode under the table. Thus users needed to drop, and hide under the table to find the passcode to finish the code.

The passcode was added to the 3D table model. In the practiceDrill controller, we added a button action which called a popUp message box to let users to enter the passcode. When the passcode was right, the drill practice was completed. When the passcode was not right, it promoted the input box to user to try again.

Machine Learning

In order to support users in learning how to secure furniture, our app needed to be able to recognize and classify real-world furniture. Although there are several good models available online, to maximize the accuracy, we trained a model to fit our specific environment and requirement.

Method

To simplify the training process and improve the result, we decided to implement our model using Inception V3 and transfer learning.

- Inception V3

The “Inception” micro-architecture was first introduced (2014, Christian Szegedy et al). In short, the goal of the inception module is to act as a “multi-level feature extractor” by computing 1×1, 3×3, and

5×5 convolutions within the same module of the network — the output of these filters are then stacked along the channel dimension and before being fed into the next layer in the network.

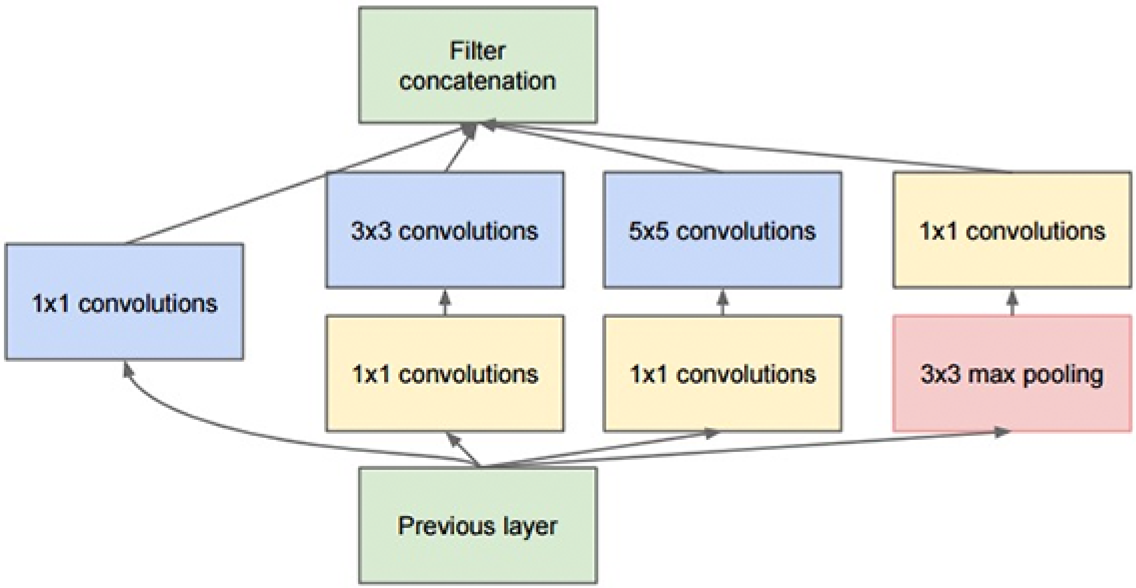

Figure 18. The basic concept of “inception”

- Transfer learning

Transfer learning is a machine learning method which utilizes a pre-trained neural network. We used pre-trained Inception V3 from Imagenet which consists of two parts:

❏ Feature extraction part with a convolutional neural network.
❏ Classification part with fully-connected and softmax layers.

In transfer learning, when you build a new model to classify your original dataset, you reuse the feature extraction part and re-train the classification part with your dataset. Since you don't have to train the feature extraction part (which is the most complex part of the model), you can train the model with less computational resources and training time.

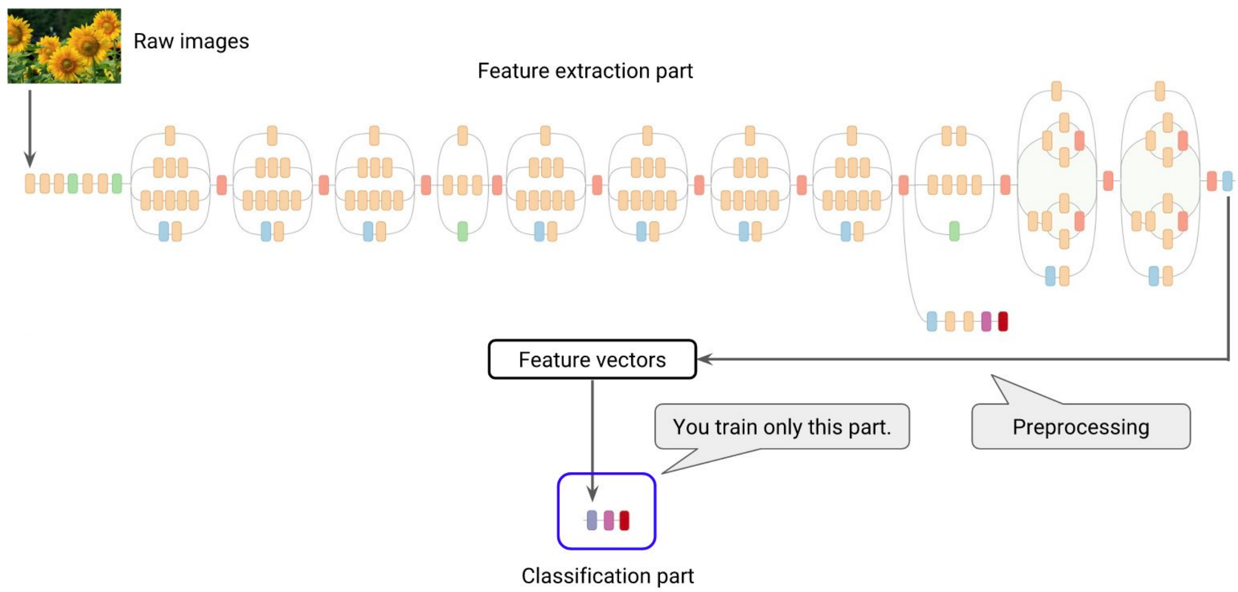

Figure 19. The process of transfer learning

After we trained the model with Keras, we converted it to an Apple Core ML model to be able to integrate our model to our app. The conversion is implemented by Core ML tools.

Dataset

For the time being, we intended to classify 5 categories in our app, which are the most common furniture or what you can find at home: bookshelves, small plants, paintings, TV, ceiling fan.

Figure 20. Examples of the training dataset

We extracted and gathered the images online. Our final dataset consists of about 200 images per category, in other words, 1200 images in all. We splitted the dataset into training dataset which contains 1100 images and testing dataset which have 200 images.

Training and Result

We use categorical_crossentropy as the metric to train the model. This is the cross-entropy between an approximating distribution and a true distribution. The cross entropy between two probability distributions measures the average number of bits needed to identify an event from a set of possibilities, if a coding scheme is used based on a given probability distribution q, rather than the “true” distribution p.
Meanwhile, we trained the model 30 epoches. At last, the testing accuracy of our final model exceeds 95%.

Usability Testing with Augmented Reality

Goals

In order to validate the flow, design of the app and use of the AR component in earthquake training, we decided to conduct a usability test. Usability testing provided us with contextual information regarding ease of use (learnability), potential for errors (errors), and whether our product achieves its purpose, which is inducing urgency about earthquake preparedness within our users (attitude) and helping them learn “drop, cover, hold-on” (effectiveness). More specifically, our research questions were:

1) Learnability: Can new users easily complete all three levels of drills?
2) Errors: How many errors? How severe? How easy is it to recover?
3) Attitude: What is the emotional response to the prototype?
4) Effectiveness: Can users recall “drop, cover, hold-on” after having completed all drills on the app?

Recruiting and Logistics

We recruited five UC Berkeley students as participants for this usability test. To recruit the users, we posted a screening survey on social media and posted links and QR codes for the survey around campus. We wanted our five participants to fit diverse profiles and chose 2 students who grew up in California and 3 who did not. This was to avoid getting opinions from a specific group of students in regards to their previous earthquake drill experiences. Since the app was still in development, during the testing, we used two versions of the app: (1) Completed design in the prototyping tool, Invision; (2) The developed “Intermediate” drill with actual augmented reality.

To create a fair testing environment, all usability tests were conducted in a room in South Hall. We moved everything out of the mid-section of the room so that users would have enough space to physically follow along with the earthquake drills as the app guided them. We had a table to one side of the room for us to ask the user about their experience with earthquakes before the testing began. We wanted to have the user start using the app while sitting down and see if the participant would willingly get up from their chair to physically drop to the floor, cover themselves with their hands, and hold on to a virtual table following the guidelines of the app (“drop, cover, hold-on”). Users were asked to complete the “Before” and “During” sections of the app, which would guide them through their tasks. Users were prompted to think aloud and describe what their thoughts and feelings were while completing their tasks. Upon completion of the app, the user was asked to sit at the desk again to fill out a post-test survey and to answer questions in a post-test interview.

Findings

- Attitude: To assess the users’ attitudes towards the app, they completed a semantic differentials activity with the following results.

	Poor (1) ~ (5) Excellent	Annoying (1) ~ (5) Engaging	Confusing (1) ~ (5) Straight forward	Ineffective (1) ~ (5) Effective	Irrelevant (1) ~ (5) Useful	Unreliable (1) ~ (5) Trustworthy
Participant 1	4	5	3	5	5	5
Participant 2	4	4	4	5	5	5
Participant 3	5	5	4	5	5	4
Participant 4	3	3	2	4	5	4
Participant 5	5	5	5	4	4	5
Total	4.2	4.4	3.6	4.6	4.8	4.6

Figure 21. Semantic Differentials

    - Straight forward (3.6): When asked why it was confusing for them, participants 1~4, those who did not give a full mark, said it was because of the switching between the two prototypes we used. Otherwise, the app "flow itself was straight forward", said users
    - Engaging (4.4): 3 out of 5 users gave less than full marks. They said that, if the app were fully developed with AR technology, it would be more engaging. However, with the current Invision prototype, it was a little difficult for them to imagine AR on Invision even after seeing the AR coded version on the other phone
    - Trustworthy (4.6): While most users rated it as trustworthy, 2 out of 5 rated it as a 4 on the trust category. When asked why, they said it was because they were never told about scenarios where no table exists or a table is far away in their previous earthquake drills. This additional scenario confused them and contradicted what they had previously been taught in school.

- Effectiveness: In order to evaluate how effective our app was in teaching participants about earthquake safety, we asked the participants the following question before and after the usability test: "If an earthquake happened right now, what would you do?". During the baseline question, 3 out of 5 participants said they would drop under a table while 2 participants said they would either run or hide under a doorway. After having tried the app, 4 out of 5 participants successfully recalled the full "drop, cover, hold-on" sequence. One participant hesitated to answer as he was not sure why he should not hide under a table that's far away. This participant was confused by the basic drill which teaches users that, in the absence of a table, one should drop and cover rather than running around to find a table to hide under

While the usability test with our paper prototype revealed confusion about how to interact with augmented reality, the second usability test with augmented reality revealed needs for improvement in the tasks we had designed in the app. Because we included step-by-step instructions to the user on what physical actions they should be completing, users understood when they should "drop, cover, hold-on". Users were able to understand that the app can actually detect your downward motion when they drop and followed along with the latter two actions after dropping. Some users actually didn't need the step-by-step guide because they already knew the recommended protocol. For these users, being hand-held through each scenario was unnecessary and created more confusion.

Another task that users expressed confusion about was the need to enter a passcode during the "hold-on" step of the augmented reality drill. Entering this passcode doesn't necessarily imitate the action of holding onto a table leg as we had hoped. Rather, users lost time trying to find the table leg that displayed the passcode. In the next iteration of our development, we will display this passcode on each leg of the table or design an easier task to confirm whether or not they've completed to "hold-on" step.

Another issue that we identified from the usability test was that users weren't always confident in the suggestions that the app provided. Users struggled to let go of knowledge they had learned from previous earthquake trainings. We hypothesize that including citations from trusted sources such as the Federal Emergency Management Agency (FEMA) or the Red Cross would mitigate users' suspicion of the app's suggestions.

Users had the most success in completing tasks within the "Before an Earthquake" section, where they were required to decide how to secure the furniture found in their living rooms. They expressed value in the ability to scan their own furniture and receive personalized recommendations for how to properly secure their surroundings.

XI. Summary of Findings

During our research on earthquake preparedness at UC Berkeley and the development of our app we discovered some key weaknesses in earthquake readiness that could be useful to universities. The two main causes of earthquake unpreparedness are misinformation or lack of previous training. Misinformation arises from the multiple sources of information students have received their training from. The protocol for what to do in case of an earthquake might have changed throughout their childhood. For example, a doorway might have been the safest place to hide in the past, but that has quickly changed with modern architecture (Earthquake Country Alliance). On the other hand, students who have not received prior earthquake training rely mainly on their instincts rather than recommended safety protocols. In interviews, the two international and out-of-state people we spoke with both mentioned that they would instinctively run outside during an earthquake. Even after conducting our paper prototype usability test, one user mentioned that "[she] would most likely forget what [she] learned and try to run outside by instinct." Relying on misinformation and instinct can be dangerous and lead to fatalities.

To ameliorate these earthquake preparedness weaknesses, we recommend reminding students of earthquake safety protocols frequently so that "drop, cover, hold-on" becomes instinctual and so that any updates in the protocol are disseminated. AR Wave allows students to access up-to-date earthquake safety information anytime and in any environment. Each scenario within the app requires and reinforces the "drop, cover, hold-on" procedure no matter what their surroundings are.

Besides bringing earthquake preparedness training to any environment, there are a few other pros and cons to using augmented reality technology. Students can practice "drop, cover, hold-on" in the environments they are most likely to experience an earthquake in. This includes their apartments, dorms, or on campus. When students are asked to secure their own, personal furniture, they are more motivated to learn. Furthermore, the app walks each user through "drop, cover, hold-on" step-by-step. This prevents users from making any initial mistakes based off of their misconceptions or instincts. The personalization and accessibility to information that AR Wave provides should be incorporated into current earthquake preparedness measures.

XII. Research Limitations and Future Work

Limitations

Our main limitations while developing AR Wave were related to constraints on time and resources. If we had more time, then we would be able to fully develop the augmented reality and use it in our usability tests rather than a prototyping tool like Invision. More time would have allowed us to run more rounds of usability testing on more iterations of our design. Eventually, we would like to partner with the Office of Emergency Management in distributing the app to the broader UC Berkeley campus and conduct surveys and research to understand how the AR might be affecting earthquake preparedness. Below we discuss the future we work we have planned for the development and design of AR Wave.

Development

Our current iteration for the development was focus on practicing earthquake drill part. For the next step of the development, we plan to develop the full features of this app to teach students the full cycle knowledge of earthquake preparedness, including

- Before the earthquake: Develop secure furnitures training feature by using CoreML machine learning model to automatically recognize common furnitures at home and teaching secure knowledge by doing quiz.
- During the earthquake: Add more scenarios to this part to teach students actions under different situation.
- After the earthquake: Using AR technology to practicing existing out the building.

In addition, we are still working on developing two features: (1) an earthquake experience and (2) a “learn AR” feature. We plan on having a virtual reality earthquake experience by providing a 360 video of an earthquake on the app that students can watch using a Cardboard headset. The “learn AR” part will be a tutorial to teach students how to interact with AR technology.

Design

The design goal for this iteration is to absorb feedback from usability test, itemize and prioritize by importance, and come up with a solution

- Restructuring the app: We are constructing a lot of UX language. Since all participants were confused by the category naming (before-during-after) in the previous usability test, we are changing it to simpler, more description terms (Earthquake drills, Home safety, and Exit Route) (Figure 22). It was also difficult for users to extinguish different scenarios under the structure of basic-intermediate-advanced, we plan to re-name these as well into descriptive scenarios: "There's a table", "No table nearby" , "People are running", and "There's a doorway" (Figure 23). Users will practice the full "drop, cover, hold-on" before other scenarios, as this is the most standard recommended action that many are aware of. Other scenarios will become activated upon completion of the standard scenario.

Figure 22. Categories are re-named from "before-during-after" to above

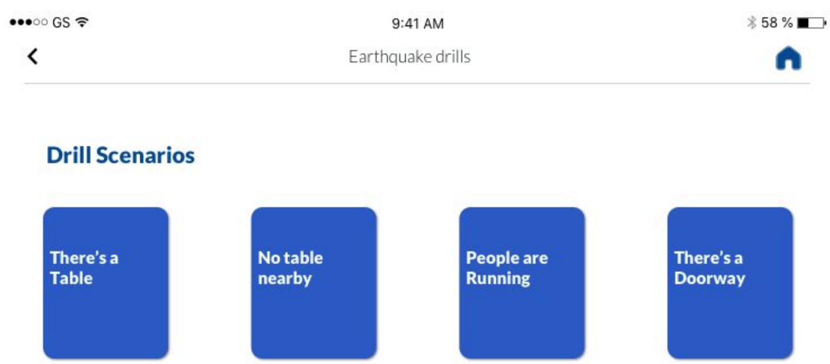

Figure 23. Previously three-levels of drills are now re-named and re-organized

- Adding explanations: We plan to provide explanation for the safety action at the end of each drill (Figure 24). This is to 1) enhance users' understanding of the safety action, thus helping them make a better decision based on the situation they are in, 2) to help users review the concept and memorize it, and 3) to persuade those who are obstinate to change their incorrect knowledge about safety actions either because of a misconception or incomplete transfer of knowledge from previous drills.

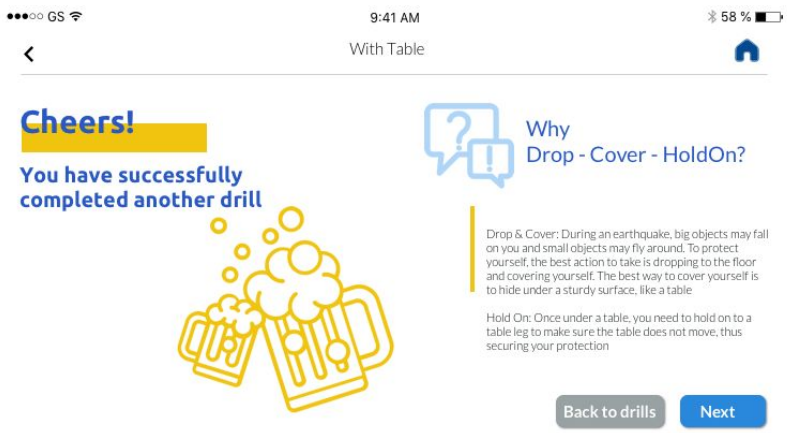

Figure 24. Explanation provided at the end of each drill

Future Directions

There are many directions we can take with the current status of the product, but these are the key improvements we plan to focus on in the next few months:

- Although those who tried our prototype highly valued the information given and expressed willingness to learn, it is unlikely that the initiation to practice the drill will come from the students themselves. Therefore, increasing visibility through various marketing efforts would create the momentum for the users to download the app and get interested in the topic.
- Once students are interested and have opened up the app, sounds effects and experiential earthquake VR video would help hook in user interest. We believe these will create more urgency and, consequently, provide users with emotional reasons to practice the drill.
- Because AR is a new technology that a lot of students are not familiar with, especially from a usability perspective, providing them with a tutorial on how to interact with AR objects would lesson confusion on user part.

XIII. References

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XIV. Appendix

Appendix 1. Survey Questions

1. On a scale of 1 to 5, how prepared do you feel about earthquake?
2. Please elaborate on your answer to the question above.
3. How many times have you participated in an earthquake drill?
4. Recalling your past experience, please describe three things you learned from the earthquake drill(s)
5. Where was your earthquake drill? (Select all that apply)
    a. Middle school or below
    b. High school
    c. College/university
    d. Work
    e. Home
    f. Other
6. How long ago was your last earthquake drill?
    a. Never
    b. Once
    c. Twice
    d. Three times
    e. More than three times
7. Do you have a disaster emergency kit?
    a. Yes
    b. No
    c. Not sure
8. Please describe why you chose "not sure" for the previous question.
9. If an earthquake happened right now, at which of these places would you have trouble figuring out what to do? (Select all that apply)
    a. School
    b. Home
    c. On the street
    d. Public transportation (Bus, BART, CalTrain, etc.)
    e. None
    f. Other
10. Are furnitures prone to falling (dressers, bookcases, etc.) secured to the wall at your place?
    a. Yes, all of them
    b. Yes, but only some of them
    c. No
    d. Not sure

11. Please describe why you chose "not sure" for the previous question
12. In case of earthquake, what are the recommended safety actions? Please describe as much as you can in one sentence
13. Which state do you live in?
14. What is your age?
15. Do you work or study at a university?
16. What is your occupation?
17. What is your affiliation with UC Berkeley, if any?
    a. Unaffiliated
    b. Student
    c. Post-doc
    d. Faculty
    e. Staff
    f. Other
18. What year are you at Berkeley?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Grad/PhD Student
    f. Other
19. Are you an international student?
20. What best describes your living situation?
    a. Dorm
    b. Apartment
    c. House
    d. Other

Appendix 2. Interview Questions

<Problems with current solution (Earthquake drill) >

Have you ever felt the need for earthquake drills? Why or why not?

Are you aware of any resources for earthquake preparation?

Have you ever googled how to prepare for earthquakes? Why or why not?

Can you tell us if you have any experience in earthquake drills, and if yes, how many times you've done earthquake drills?

- When and where were these drills held?
- Recalling your memory of those drills, please describe your experience step by step. What was the drill process?

- Was there anything confusing?
- What was your takeaway from the drill?
- How prepared did you feel about earthquake before and after the drill? (On a scale of 1 to 5)
- Why did you feel that way?
- After the drill, did it lead you to make some changes in your environment? (ex. Prepare an emergency kit, secure furnitures to the wall, etc.) Why or why not?
- Would you recommend your friend to go through the drill at least once if the friend have not done it yet? Why or why not?

<Level of Preparedness>
Let's say there is an earthquake right now. What would you do? (See if the interviewer can recall "Drop, Cover, Hold On")

Thinking about your daily routine, which places that you visit frequently would you have trouble figuring out what to do in case of an earthquake? Why? Could you elaborate?

(Skip if already discussed) Do you know that furnitures need to be secured to the wall?
(Skip if already discussed) Do you have an emergency kit?

Can you tell us what would need to be in an emergency kit?
Where would you store it and why?

<Student Knowledge/Confusion>
Now that you have had a chance to think a little bit about earthquake during this interview, are there any questions that come to your mind? What are they? Why are they important yo you?

<Awareness Level for Danger of Earthquake>
Can you tell us your current understanding of earthquake danger in California, if any?
How long have you lived in the western part of the country?

Appendix 3. Usability Test Script

Intro

Hello! Our names are Anna, Priyanka, and Sophie and we are a group of researchers studying how augmented reality might be used for earthquake preparedness.

Consent

Before we start, we wanted to go over some of the legal stuff. With your permission, we will video and audio record this session. The recording may be used for educational research purposes, but we will mask any personally identifiable information before we share this recording with anyone else outside the three of us. Begin recording upon receiving consent form.

Today's session will consist of three parts. First, we will ask you some preliminary questions about your experience with earthquake preparedness and, second, we will ask you to complete a few tasks using our phones. After these tasks, we would like to ask you a few follow-up questions. We want to remind you that this is not a test and there is no right or wrong answer. Any feedback you give us, either positive or negative, is helpful for us, so please feel free to express whatever thoughts you have while performing these tasks. That said, we ask that you think aloud while performing these tasks.

Preliminary Questions

- What year are you?
- Where are you from?
- When and where was the last time you had an earthquake drill?
- How familiar are you with augmented reality?
- If an earthquake happened today, what would you do?

For this part of the testing, you will go through multiple earthquake drills. Because only some of our app is actually coded, we will switch between different phones to have you use different prototypes. But please imagine that these different prototypes are one cohesive app.

Tasks

- Feel free to move around during these tasks as it is using augmented reality.
- Task 1: Go through this app and complete the basic earthquake drill. Please try to think aloud during this process.
- Task 2: For this part of the test, we want you to just tell us what you'll do instead of actually clicking on the screen. This is because at one point, we'll have to switch out the prototypes.
    - After switching phones: We want you to imagine that the table we see is the virtual table we just saw
- Task 3: From here on you can feel free to interact with the app. Please complete the next level.
    - After task:
        - What did you find useful or unuseful?
        - What did you find confusing?
        - What do you think you've learned?

        - Do you feel the need to replay the game? Why or why not?

- Task 4: Now go through the before earthquake part.

<u>Post-Usability Test Survey</u>

- What are some steps you should take before the next earthquake hits?
- If an earthquake were to occur right now, what would you do?
- On a scale of 1 to 5 (1 being poor, 5 being excellent), how would you rate your experience?
- What are two things you found frustrating about the design of the app?
- What are two things you liked about the design of the app?
- Was there anything that surprised you or was unexpected while completing these tasks?
- Would you recommend it to somebody else?
- Any final comments or feedback you'd like to tell us?
- Semantic Differentials
    - Annoying _ _ _ _ _ Engaging
    - Confusing _ _ _ _ _ Straight Forward
    - Ineffective _ _ _ _ _ Effective
    - Irrelevant _ _ _ _ _ Useful
    - Untrustworthy _ _ _ _ _ Reliable