Curing fears in a virtual environment - Phobias Curer

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1. EXECUTIVE SUMMARY

1.1 Key Problem

Fear can be a major cause of emotional and physical distress, where the effects can range from weakening of immune system, cardiovascular damage, and lead to gastrointestinal problems such as ulcers and irritable bowel syndrome, and decreased fertility. Fear alleviation has been an active area of research for the past few decades. Recently, neuroscientists have figured out how to remove specific fears from patients' brains using a combination of artificial intelligence (AI) and brain scanning technology, which could potentially help people with crippling phobias.

Alternative non-invasive techniques like systematic desensitization have been consistently proven to be effective in the treatment. In this procedure, events which cause anxiety are recalled in imagination, and then a relaxation technique is used to dissipate the anxiety. Even though this technique is really powerful, it requires the patient to physically interact or be present in the environment which contains the feared stimuli. We propose an alternative for alleviating fears through systematic desensitization in an “Augmented Reality” environment.

1.2 Design Ideas

With the advent of plethora of AR devices in the market such as Google Glass, Microsoft Hololens, MagicLeap etc., we are about to witness a transition to a world where AR devices will become ubiquitous. The recent success of the game Pokemon GO is just the beginning of this shift. For this project, we use Microsoft Hololens for prototyping our AR based solution. This not only removes the problem of direct interaction, but also provides a false sense of security to the patient. In our system, we gradually desensitize our patient using a level based approach to handle one particular use-case: Arachnophobia, the fear of spiders. Moreover, for assessment of fear experienced by the patient, we use self-reporting to gather the data for the results. However, self-reporting is not a fully reliable method and therefore, to corroborate user feedback, we use Heartbeat rate (HR) as well.

1.3 Implementation

Our work is primarily inspired by the work of [Ost et. al, 1991], in which a patient is exposed to Spiders in different degrees of scariness and their feedback is recorded by themselves and a physician.

To make this system fully self-reportable, we used a level based architecture. A patient can login into the Hololens device and Web Application, using a token based authentication. To track their progress, the patient can see their usage data on the Web Application. In an appempt to mirror the actual experiment, we present the user with a pre and post treatment survey to determine their level of fear. We used Hololens as our AR device to show holograms of spiders in different scenarios, with fear increasing at each level. We have used a Web Application based on LAMP stack hosted in AWS cloud to track the users' data generated by their trails.

1.4 Features

The key features of our application are

- *Hassle Free Authentication* - Token based authentication to avoid any typing by the user, since it's very cumbersome to type in a Hololens device using finger based click gestures
- *Level based architecture* - To give the patients a logical view of level of fears and full control over the kind of exposure they want of the spiders.

- *Data Tracking* - We have enabled web based analytics integrated within Hololens device to keep full track of the fear levels experienced by the user in each use, for each level. The progress can be tracked on the WebApp.
- *Speech Based Navigation* - Similar to authentication, to make the user experience click free, the navigation between levels and menu is voice activated.

1.5 Testing & Evaluation

- *Testing*: For testing, we designed an experiment which first tests the eligibility of the test subject with arachnophobia using a pre-assessment questionnaire. If the test subject is eligible, they rate their experience of each of the fear levels inside the AR application on Hololens. After the study is completed, the user fills another questionnaire and this, along with their progress over multiple sessions is used for final assessment.
- *Evaluation*: Typically, a treatment consisting of curing a Phobia requires a continuous exposure to the fear causing agent and tracking the progress of a patient over a period of 3-6 Months. Since we don't have so much time, we were only able to get the ratings for the fear levels and feedback for the usability of the product from 5 participants over 2 days.

1.6 Future Directions

PhobiasCurer is still in its nascent stages, there is a lot more that we have planned for this. We hope to add the following features to our project:

- Increasing the scope of the testing to multiple patients over a longer duration
- Improving quality of the objects inside the levels. Currently it does not look life like and we plan to collaborate with animators/designers to get the levels look more realistic
- More fears in addition to arachnophobia like fear of rodents, cockroaches and others
- A mobile phone application for patient login and viewing their personal data1

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Fear is a feeling induced by perceived danger or threat that occurs in certain types of organisms, which causes a change in metabolic and organ functions, and ultimately a change in behavior. Management of fear is usually done in 2 ways: Pharmaceutical and Psychological. For psychological fears, an active and successful approach involves exposure therapy where repeated confrontation with the fear inducing stimulus helps in pacifying fears using Cognitive Behavioral Therapy. However, this usually involves real-life interaction with the stimulus and presents a lot of issues. We propose a method to simulate this procedure using augmented reality to remove those issues.

Additional Key Words and Phrases: Arachnophobia, Microsoft HoloLens, Fear alleviation, Fitbit tracking, Augmented Reality, Ubiquitous Computing

1. INTRODUCTION

Fear is one of the primary emotions in many organisms. It is one of the few emotions that evolved as a primal instinct for survival amongst humans for our reaction to danger. Fear cannot only cause emotional distress but can also be responsible for changes in organ functioning in the body. Phobia is one of the conditions that is associated with fear and is defined as a type of anxiety disorder involving persistent fear of an object or situation. Sometimes the person affected may go to great lengths to avoid the situation/object, which is sometimes much greater than the actual danger posed. One of the common phobias is the fear of spiders, also known as arachnophobia. Usually phobias are cured by continued exposure of the fear inducing agent to the subject, so that the effect of the object on the person can be reduced. For instance, in the case of arachnophobia, it may involve keeping the subject in the same room as a spider, which is present inside a box or might actually involve the subject interacting (touching) the spider. However, real-life exposure might be extremely uncomfortable for the subject and recreating the situation might be difficult for the therapist as well. We illustrate the advantages of using AR and VR environments as compared to traditional treatment, which we list in Table 1. Therefore, we propose a solution for simulating this environment using an augmented reality device.

Table I. Advantages of augmented and virtual reality for treating psychological disorders.

Traditional Treatment	AR and VR Treatment
Treatment occurs in a real environment, where the elements the patient fears are also real and might virtual, not behave as the therapist desires.	Because the elements that the patient fears are virtual, they can't hurt him or her.
The therapist might have to take the patient to a location the patient fears or re-create it. Access to this place could be complicated and the therapy might require several sessions.	In AR or VR scenes, the virtual elements can appear whenever the therapist wants. Access to the scene is as easy as running the program.
The therapist does not control the order in which stimuli are produced.	The therapist controls stimuli generation and can repeat the stimuli as many times as necessary. The therapist also controls the virtual elements' order of appearance and can start or stop the program at any time.
The therapist cannot ensure that the patient will be completely safe during the treatment.	The virtual elements aren't real, so there's no real danger to the patient.
The real place could be public. The patient might suffer a panic attack during the treatment, embarrassing both the therapist and the patient.	The therapist chooses where to run the program, so can control all possibilities.

We use Microsoft HoloLens, an augmented reality device, for creating an AR application in which user can be exposed to fear while wearing the device. Instead of a real-life experience, the AR application will augment the fear stimulus into the natural environment of the user, thereby making the user believe the presence the object, in our case spider. One limitation of AR against VR is that situational and environment based phobias cannot be handled in AR and therefore, we picked up one of the most common object based fear for our project. More details are presented as follows.

In section 2, we explain the various phobias, greater insight into how the traditional methods for alleviating fear work and current research in the field.
In section 3, we talk about the design of our system. It includes the flow of the entire solution that we created.
In section 4, we discuss the current architecture of the project, the components, layers and the technologies used.
In section 5, we discuss the testing and evaluation approaches. We specifically discuss the role of heartbeat and how it is integrated with user feedback.
In section 6, we discuss the roles and responsibilities, tools used and our learning from this.
In section 7, we discuss the future directions and what we plan to integrate later.

2. MOTIVATION AND BACKGROUND

Figure 1: UC San Diego Assistant Professor Dean Acheson is conducting an arachnophobia pilot project supported by CTRI. Here he is with Rosie, the tarantula, and Assistant Mary Kamenski in the spider room at UC San Diego.

Arachnophobia is the extreme fear of spiders. A significant number of individuals have phobias, many are untreated. Arachnophobia can be reliably treated with behavioral therapy, specifically in vivo systematic desensitization; some studies posting results as high as a 75 percent success rate. We are attempting to bring a tested and proven method to the HoloLens, ultimately showing a more efficient and cost-effective method for curing Arachnophobia and phobias in general.

Conventional treatment of Arachnophobia [Marshall et al, 1990] involved patients sitting near real Spiders. This resulted in a high dropout rate from the treatment. We want to address this problem, where we aim to create an ecosystem where a user, using ubiquitously present AR devices, can treat themself while monitoring their own progress. This also takes care of the problem of the fear induced by in-vivo interaction by providing a sense of security to the patient. A level based architecture ensures that a patient has full control over the degree of fear that they want to be exposed to. This uses the concept of behavioral therapy, which a widely used method to cure Arachnophobia, and phobias in general.

There have been many studies and research done accessing different approaches with the primary motivation of increasing the efficiency and cost-effectiveness of treatments [Öst et al, 1991] [Botella et al, 2010]. With a solution using the HoloLens, we aim to show the advantages of current Augmented Reality (AR) technology in treating Arachnophobia in a way that can be primarily self-administered and effective. Further, as AR technology and hardware matures, cost will continue to drop for the hardware and the effectiveness will increase due to the better graphics and sensors.

Our approach relies heavily on behavioral approach as a guide since heart rate by itself is not a reliable approach. One of the biological behaviors that is affected by fear is increased in heart rate, which is advantageous in evolutionary term because it increases the blood flow to the subject allowing them to improve their physical capabilities in case they need to escape. It also causes the subject to be more alert as it will aid in survival. We use a traditional questionnaire [Kozak et al, 2003] to judge how the patient felt in the user, and provide synced heart rate data to the therapist to supplement it.

The advantage of using Augmented Reality [Joan et al, 2005] versus Virtual Reality is the focus on intractability and mimic traditional in vivo techniques. The patients can simulate interacting with the object of their fear, in our case spiders, which is a vital component of treatments. A common final step is having the spider in the patient's hands. Additionally, traditional treatments involve tasks involving the spider, such trapping a spider and throwing it out. All these can be simulated almost completely identically with Augmented Reality, but not Virtual Reality.

There have been many studies attempting to cure Arachnophobia through therapist-guided exposure as well as self-directed exposure. The approach we are taking leverages advantages of self-directed exposure, but also relies on trained professional. There is significant evidence that self-directed exposure is not as effective. We are focusing on a procedure that relies on a psychiatrist or trained professional as a guide, but provides a very easy and convenient setup, that could lend itself to self-directed applications. We provide the trained professional with a questionnaire and heart rate data after each trial, as well as a Web Application to track progress over time. This could also be made available to the user and enable self-directed procedures after the initial guided treatment. There have also been studies using VR, or lab-created AR, and recently with the HoloLens as well. Levels are common in all treatments as they enable the patient to slowly grow comfortable with a level of fear. Coupled with a questionnaire and clear instructions, defined levels also help the user in self-treatment.

There are some problems with our level-based and questionnaire oriented approach. First, the levels are uniform across patients, and the jumps in between the levels will be better suited to some users than others. Further, self-assessment is not always a reliable form of assessing a treatment, especially if the patient is anxious or afraid.

One strength of systematic desensitization comes from research evidence which demonstrates the effectiveness of this treatment for phobias. McGrath, [McGrath et al. (1990)] found that 75% of patients with phobias were successfully treated using systematic desensitization, when using in vivo techniques (see below). This shows that systematic desensitization is effective in treating phobias.

Extension: Further support comes from Gilroy et al. (2002) who examined 42 patients with arachnophobia. Each patient was treated using three 45-minute systematic desensitization sessions. When examine three months and 33 months later, the systematic desensitization group was less fearful than a control group (who were only taught relaxation techniques). This provides further support for systematic desensitization, as a long-term treatment for phobias.

However, systematic desensitization is not effective in treating all phobias. Patients with phobias which have not developed through a personal experience (classical conditioning) for example, a fear of heights, are not effectively treated using systematic desensitization. Some psychologists believe that certain phobias, like heights, have an evolutionary survival benefit and are not the result of personal experience, but the result of evolution. These phobias highlight a limitation of systematic desensitization which is ineffective in treating evolutionary phobias."

3. DESIGN

Heart-Rate Sensor

Initially, we envisioned the use of PhobiasCurer to be a ubiquitous system that will seamlessly combine the heart rate of the user, its changes, and the HoloLens application to form a holistic program that will adjust the stimulus level of the phobia or augmented environment based on the user's current physical and mental state. To achieve this, we planned to use an external heart rate sensor, a wireless fitbit device, to track the user's heart rate at all times while using the HoloLens and stream that heart rate data in real-time back to our HoloLens application. Our application would then use the user's current heart rate or what the application perceives as the current heart rate to determine the amount of fear and stress they are currently experiencing, and adjust the level of stimuli provided accordingly to both challenge the user's fear while not overwhelming the patient. Ideally, the application would increase the level of stimuli after the user has gotten accustomed to the current level and is no longer experiencing much fear, but also decrease the level of stimuli if the user is too overwhelmed by the current level they are exposed to and allow the user to apply the relaxation technique described by the psychologist to re-establish the relaxation response that will inhibit the original anxiety response [McLeod, Saul 1970]. However, through the process of implementing our application we decided that this original design had both technical issues and fundamental flaws.

We encountered much difficulty attempting to stream real-time heart rate data from the fitbit to our HoloLens application. Although the fitbit provides an API for data access, on its fastest settings the heart rate data is only updated every 15 minutes. This is a crucial problem within the context of our design because our application must rapidly respond to the user's heart rate and make stimuli changes when appropriate. This slow response time raised safety concerns for the user due to the sensitive physiological nature of the treatment. For example, the user could have a panic attack if the environment was not controlled correctly [NHS Choices 2016]. To solve our technical problem, we explored some alternatives but ultimately ran into dead ends. We looked into the Microsoft Band2, another wireless wearable heart rate sensor which potentially had a faster refresh rate on its data, but the SDK for developing applications with the Band2 was no longer supported by Microsoft. We looked at the PIP wireless biosensor, but the data it gathered was only accessible through its own phone app, and we could not find a way to stream it to our HoloLens application.

In addition to technical concerns, as we did more research into desensitization therapy, we realized our original prototype had more fundamental design issues. Due to relying completely on the user's heart rate data to control the level of stimuli, we are taking control of the stimuli away from the users and psychiatrists, which is the exact opposite of the principles of the treatment, which relies on giving the users control over the level of exposure to the stimuli given their own current physiological state. For example, the user needs time to readjust their mental state and revert back to the previous level of exposure if the current exposure level is causing them too much anxiety. However, it is difficult to have our program know which level to revert back to and for how long the user should stay in that level by just using the current heart rate data because the user's normal physiological state could change throughout the treatment. Furthermore, the user may feel that they are ready or not ready for the next level of exposure, but because the way the application allows them to progress to the next level of exposure or not is dependent on how it interprets the user's current physiological state by using their heart rate data, the user essentially does not have a say in the progression of their treatment. This problem of potentially locking a user in a level they are not ready for is exacerbated by the concern of increased heart rate not being able to necessarily quantify the amount of the fear they are experiencing in every patient, as due to the different physiology of humans, there is a variance in how much their heart rate increases in response to the same stimuli, especially between men and women [Kuschyk, MD Juergen 2007] . Thus, the combination of technical difficulties and these potential safety concerns caused our design to move away from stimuli being controlled by real-time heart rate data, and we came up with a system in which the user or psychiatrist has full control over the stimuli presented to the user at any given time. In addition, with the above changes to our design, we felt that it would be better to move away from the counter conditioning method of relaxation and move towards a combination of systematic desensitization and flooding technique instead [McLeod, Saul 1970]. The exact mechanics of the levels and level switching will be covered in the next section focused on the HoloLens application.

Although our final implementation no longer uses heart rate data to control our HoloLens stimuli, we believe heart rate data to still be useful in aiding psychiatrists in their treatment of phobias as well as aid our application in better understanding how the levels we constructed induce fear. As such, in our evaluation of the application on test subjects, we sample the subjects' heart rate with a fitbit device before the start, the middle, and just after they exit each level. We believe this data to be useful in helping us develop levels that increase the effectiveness of the treatment by identifying levels which are not inducing as much as fear as we expected, levels which induce more fear than we expected, as well as identifying any potential big jumps in fear level induced from one level to the next higher one. We can then use this data to fine tune our levels to make sure each jump to the next level is reasonable, and the stimuli is appropriate for each level. The heart rate data collected would also help psychiatrists identify how far along the treatment the patient is at after each session with PhobiasCurer, and determine which levels to expose the patient to next. In the future, we believe streaming the heart rate synched with a video of exact what the patient sees in the HoloLens to also be helpful in determining which specific parts of our levels are working well and which need adjustment.

Final Design

The design of the solution was influenced by systematic desensitization, which resulted in a level based approach taking fear of the patient into account and accessing user data for evaluation. This also involved login capability as well as historical records for a particular patient. The goal was to create a solution through which feedback collection through the user is easy and it seamlessly integrates the different components of the system.

After considering various different approaches and prototypes for the application, we finalized the following prototype:

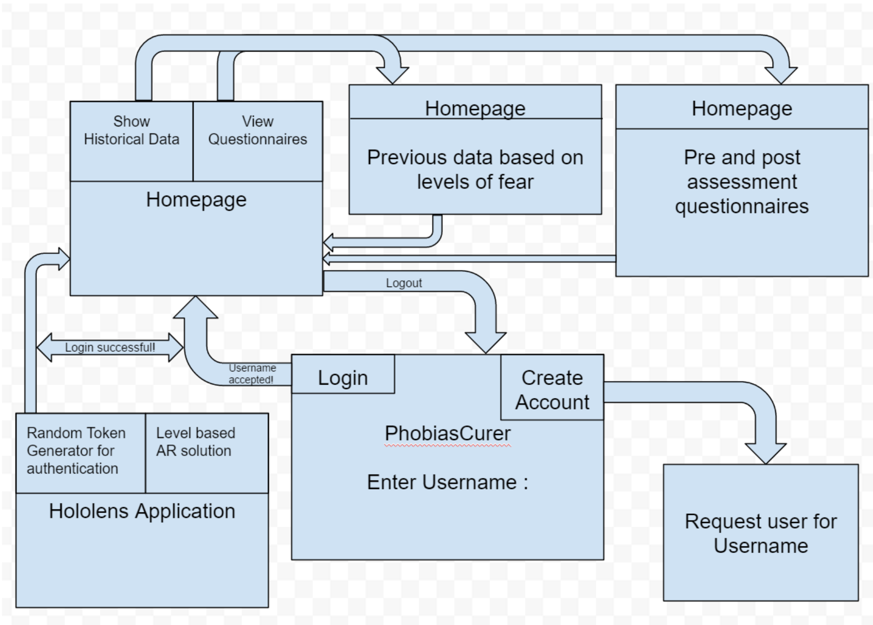

Figure 2: Schematic Workflow for our application

Based on the prototype in Figure 2, we started with the implementation of the AR application using HoloLens in Unity using C#. After the AR application loads, Figure 10 shows the token generation screen inside the AR app. After verification of the token using the Web App, we see the Menu inside the HoloLens (Figure 11). From there, we can navigate to other levels.

Once the user has given a rating to a level after it ends, her rating is persisted via an API call to our server in our Database for future access. Figure 3 shows the login screen for the user which facilitates logging in and creation of a new username. Once logged in using the token generated, the user can view their pre-assessment questionnaire (Figure 4), post-assessment questionnaire (if the study is already finished) and their historical data (Figure 5).

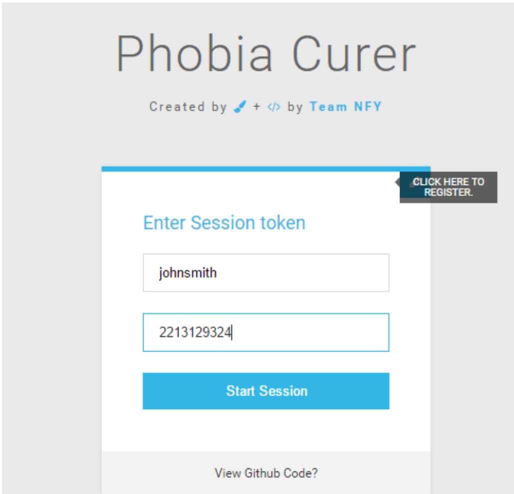

Figure 3: Login Screen

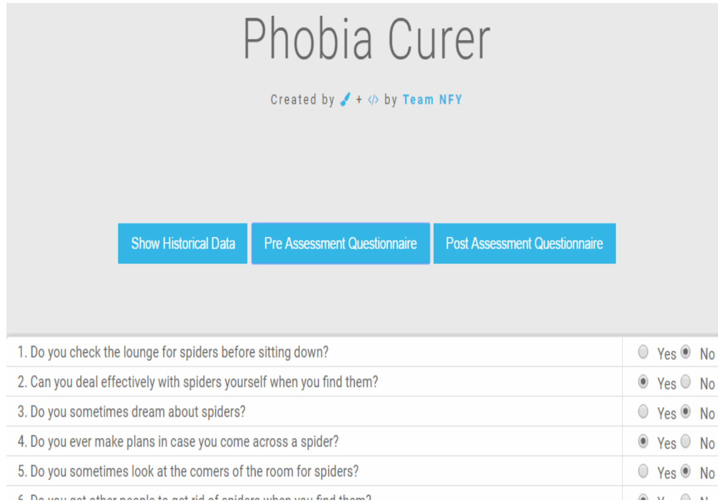

Figure 4: Homepage with Questionnaire history

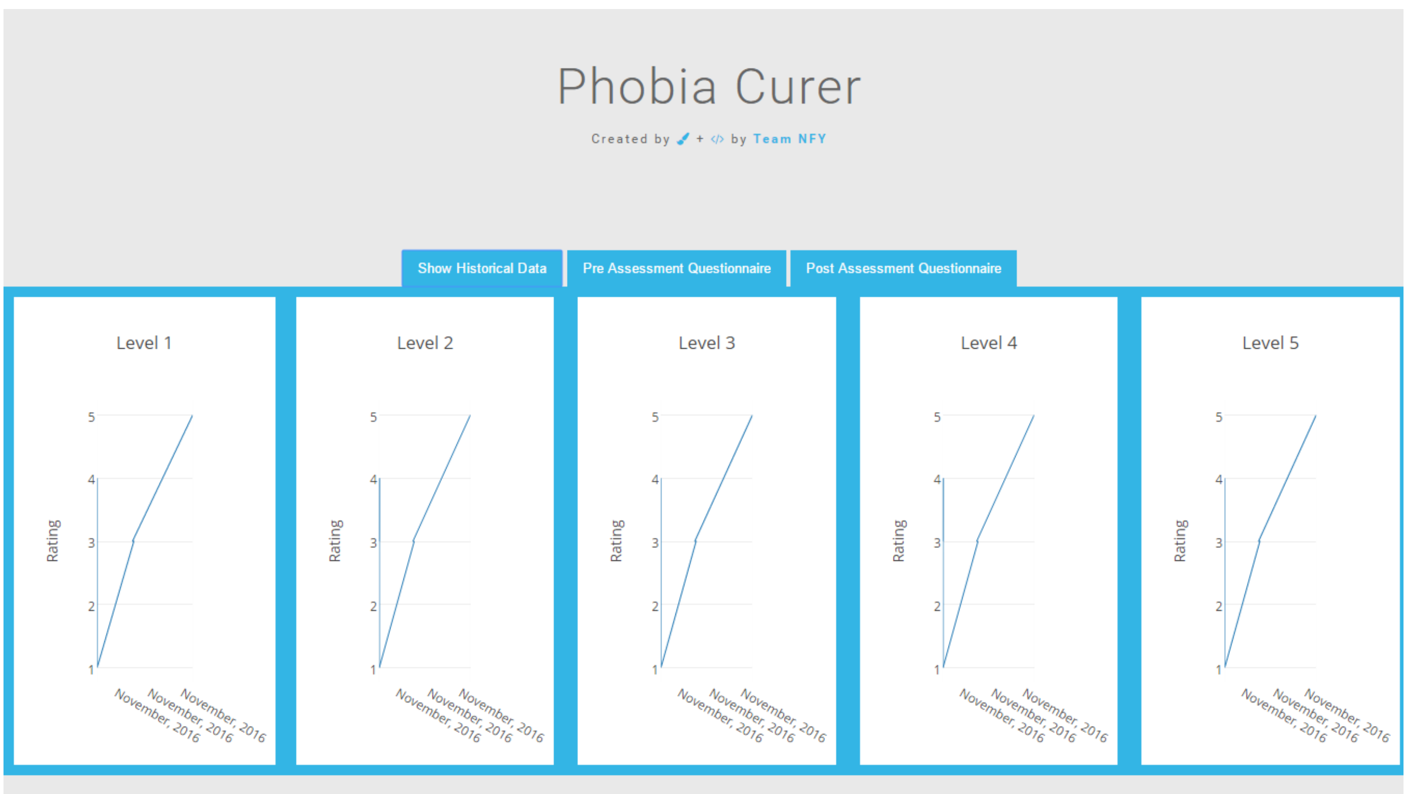

Figure 5: Historical Data for a given test subject. In this image, each graph corresponds to one level. The X-Axis is the date on which user last logged into the AR application and Y Axis denotes the rating for how much fear the user felt, 5 being the highest.

4. SYSTEM DEVELOPMENT

4.1 Architecture

One of the most challenging factors of our project was time. In the limited time that we had, we needed to come up with a solution for which we could use the agile methodology and therefore we needed to come up with a Minimum Viable Product (MVP), which would not only serve as the base of our AR solution but also be easy enough to modify and improve for the future iterations. In addition to this, we had to look at the cognitive aspect of handling fears and how fear alleviation is done in real life. We found that it is done by gradual exposure to the fear inducing stimulus and therefore we decided to go with a level-based approach for the AR application. This was chosen mainly so that the basic level could be implemented and the other levels could be built on the top of it. Therefore, the AR solution has been divided into multiple levels in which a higher level number indicates an increase in the fear experienced by the patient. Moreover, for the Hololens based app, we have tried to keep things as modular as possible so that each level could be handled separately and it does not depend too much on any other level except level one, which is in fact, Menu.

We used a client server layered architecture. We divided our system into multiple functional components and used logical connectors to interconnect the components. This helped us break our system into more manageable independent units. Such an architecture promoted flexibility and comprehensibility within our system. A flexible system ensured that we could add or make changes to our existing functionalities without having to change the entire system design. Furthermore, comprehensibility as achieved, helped us evaluate and study each component in isolation thereby, promoting independent development. Finally, the aforementioned architecture helped us resolve risks at every iteration and allowed us to tackle such risks at the component level thereby rendering them more manageable as opposed to having tackle risks at the system level.

4.2 Operational Flow

As shown in Figure 6, our system has been divided into 3 tiers, namely, the Data Tier, the Presentation tier and the Logic Tier:

4.2.1 Database Layer - As the name suggests, this layers forms the central repository as used by the application in order to store information related to specific users. Components at the application layer query the database to retrieve and validate user information which is further used while tracking user progress as they use the application.

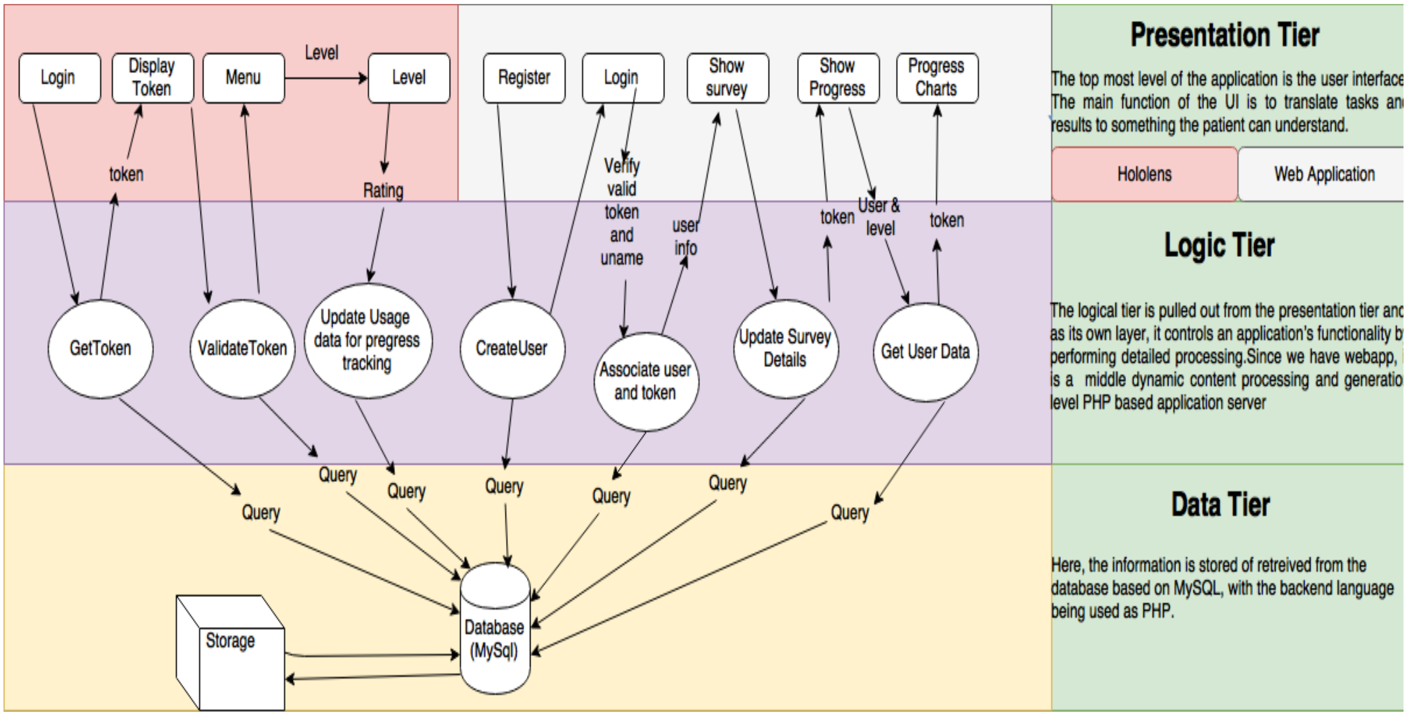

Figure 6: A scheme of our architecture

4.2.2 *Application Layer* - This layer forms the crux of our project. It comprises 4 main components named, the signup component, login/edit, and the update progress component:

4.2.2.1 *Get Token* – This component is designed to minimize the typing done by the user while wearing the HoloLens. A person wearing a HoloLens gets a random token generated by the server. The user then signs in to our Web App using this token, which tells us which user is currently using which HoloLens device. This makes the login process pretty hassle free.

4.2.2.2 *Validate Token* - This component is called once the user has entered his username and dynamic token into our Web App. If it returns true, that means the token was associated with an existing user name and the HoloLens app is ready to be used. After the validation, the user is redirected to the Menu.

4.2.2.3 *Update Usage Data For Progress Tracking* - This component is called by the presentation layer after a user is trying to exit a level and going back the menu. It updates the level of fear experienced level by the user on that day and saves it to our database.

4.2.2.4 *Create User* - This component is called by the Web App once a new user is trying to register herself. Upon successful registration, the user is redirected to the login page.

4.2.2.5 *Associate User and Token* - This component is called by the login page of our Web App once the user has successfully generated a new token and is trying to login to our Web App. This

Figure 9: A scheme of our architecture

essentially established the link between a user row and his data in our table. It returns the survey information of the user, which helps us make the layout of the Web App.

4.2.2.6 *Update Survey Details* - This component is called by the Web App when the user tries to take the pre-treatment survey and post-treatment survey.

4.2.2.7 *Get User Data* - This component is called by the Show progress widget in our user interface. It fetches all the data points of the progress generated by the usage of the app by a particular user.

4.2.3 *Presentation Layer* - The presentation layer can be categorized into two components:

4.2.3.1 *HoloLens* - consisting of the Login, Display Token, Menu and Levels components.

4.2.3.2 *Web App* - consisting of the Register, Login, Show Survey, Show Progress and Progress Charts.

4.3 Technology

In this section we will describe the technology used to implement the solution. The HoloLens is used for the holograms. The display of the fully functioning body was explored with augmented reality but found that virtual reality will make for a more immersive experience.

4.3.1 *HoloLens* - The HoloLens is a head-mounted display unit connected to an adjustable, cushioned inner headband, which can tilt HoloLens up and down, as well as forward and backward. To wear the unit, the user fits the HoloLens on their head, using an adjustment wheel at the back of the headband to secure it around the crown, supporting and distributing the weight of the unit equally for comfort, before tilting the visor towards the front of the eyes.

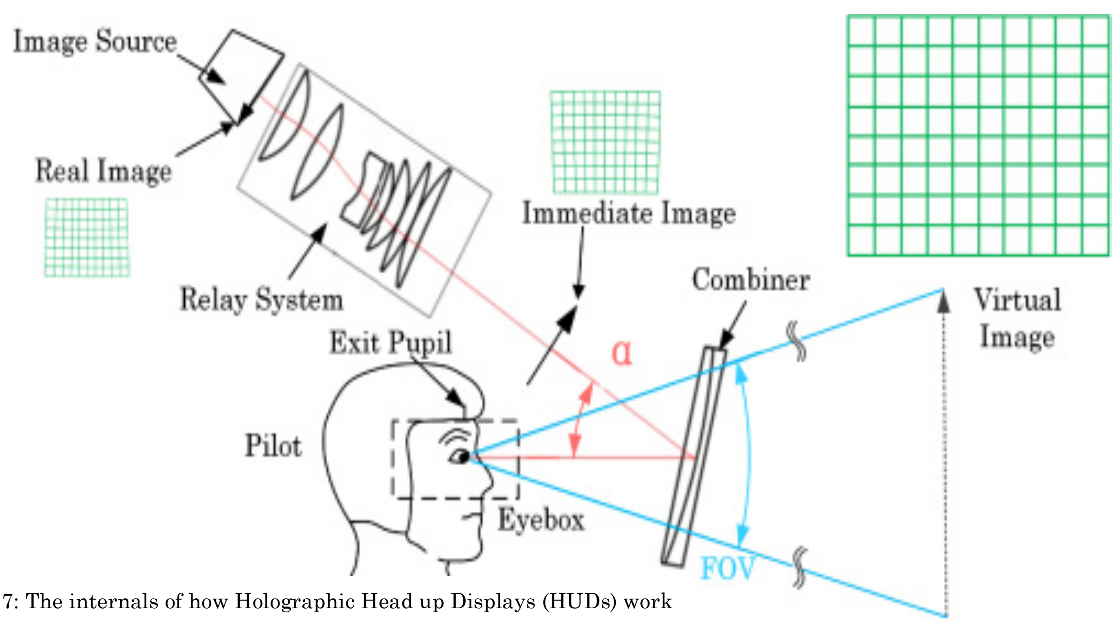

Figure 7: The internals of how Holographic Head up Displays (HUDs) work

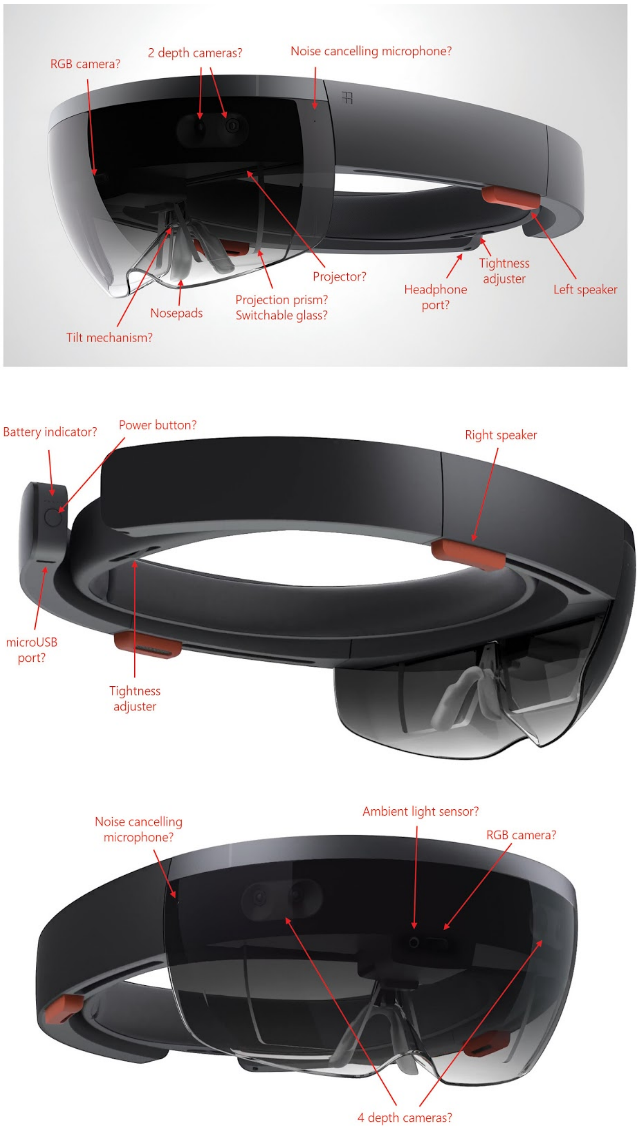

Figure 8: HoloLens sensors and components

The lenses of the HoloLens use optical waveguides to color blue, green, and red across three different layers each with diffractive features. A "light engine" above each combiner lens projects light into the lens, a wavelength which then hits a diffractive element and is reflected repeatedly along a layer until it is output to the eye.

4.3.2 Fitbit Fitness Tracker - Fitbit is a device that you wear on your wrist that logs biometric data of the user. It can serve as a pedometer, heartbeat monitor, sleep tracker, and much more. We only use the Fitbit for monitoring heartbeat in this project.

4.3.3 *Software* - The software used in this project includes; Unity for HoloLens 5.4, HoloToolkit, Vuforia SDK, and AWS for hosting, LAMP for server development.

4.3.3.1 *Unity For HoloLens 5.4* - Microsoft and Unity have been working closely to provide Unity developers the tools to create Mixed Reality (MR) applications for HoloLens. Using this software facilitates development of a single application compatible with HoloLens, Android, iPhone etc. Additionally, regular Unity versions do not support HoloLens export.

4.3.3.2 *HoloToolkit* -This is an open source SDK provided by Microsoft for HoloLens developers. It contains numerous examples for Text to Speech conversion, Speech Recognition, many assets for free use, multiple sample demos for AR app development.

4.3.3.3 *Amazon Web Services (AWS)* - AWS offers a suite of cloud-computing services that make up an on-demand computing platform. We used the include Amazon Elastic Compute Cloud, also known as "EC2" to host our web app.

4.3.3.4 *LAMP* - It is an archetypal model of web service stacks made up of the Linux operating system, the Apache HTTP Server, the MySQL relational database management system (RDBMS), and the PHP programming language.

4.3.3.5 *Vuforia SDK* - Vuforia enables you to create holographic apps that can recognize specific things in the environment so that you can attach experiences to them. We use Vuforia to place a spider on a marker placed on a user's hand.

4.4 Features

In order to implement the product, we divided our solution into the following features:

4.4.1 *Hassle-free Authentication* - Authentication is one of the important aspects of our application. This contains 2 parts: token generation and token verification. Token generation involves generating a random token on the server. The Hololens call a token generation API to get a random token. That token is then displayed by the HoloLens app, and is used to login into our Web App. This has one major advantage: It saves the effort of typing on the HoloLens app, which is an extremely arduous task. Token verification involves access to the AR application. Once a token has been generated and used for login, the token and username are associated with each other and stored in the database. After this step, unless the AR app verifies that the randomly generated token has been associated with a username, it does not let the user the proceed and access the Menu of the AR application, from which user accesses the further levels. This feature can be seen in Figure 9 and 10 below.

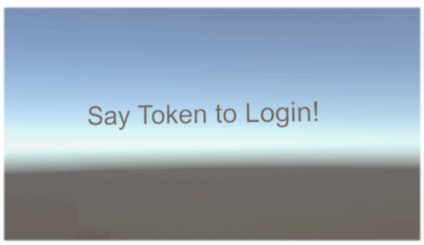

Figure 9: AR app starting scene

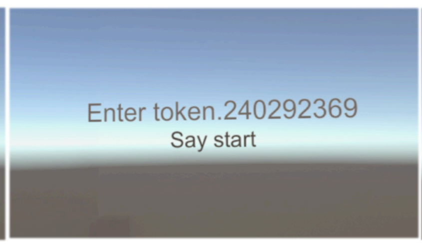

Figure 10: AR App token gen. scene

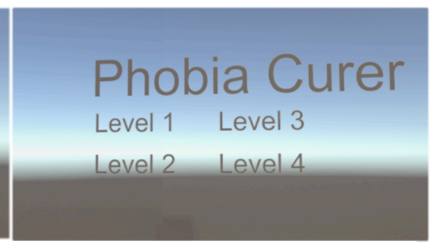

Figure 11: AR App menu

Figure 12: Level 1- Static Spider

Figure 13: Level 2 – Spider in box

Figure 14: Level 3 – Spider walking

Figure 15: Level 4 – Spider walking towards you and always facing you, with option to modify opacity using speech commands

Figure 16: Level 5 – Rendering a spider on your hand using Vuforia. The hand is not show here due to Vuforia limitations.

Figure 17: Level 5 - Marker on which the Spider showing in Figure 15 gets rendered.

4.4.2 *Level based architecture* - We have used this architecture to make sure that an agile incremental approach could be used for development[Ost et al, 1991]. This not only helped us make sure that we could develop a minimum viable product which can be expanded and reiterated upon for future levels, but also helped keep it modular. Moreover, this level based approach helped us integrate the cognitive aspects of fear and fear management and make sure that we could test out different strategies and choose to select the ones which are viable for usage. This feature can be seen in Figure 11. The levels are as follows:

- Level 1 – Static Spider (Figure 12)
- Level 2 – Spider in a box (Figure 13)
- Level 3 – Spider walking (Figure 14)
- Level 4 – Spider walking towards you and always facing you, with an option to change opacity to make it disappear giving the user control of the situation (Figure 15)
- Level 5 – Rendering a spider on your hand (Figure 16). Note that Vuforia uses the main HoloLens camera for rendering the image and therefore it does not show the marker or user’s hand in screenshot. Figure 17 shows the marker on user’s hand.

4.4.3 *Data tracking* - Data tracking is another essential aspect of our application. Our application aims at assessment of fear over time and recording the data obtained from self-reporting and heartbeat monitoring. Through this feature, we see how a user’s fear varies over time and whether the current application and levels are helping the users. If the application is not helping the user, the application could possibly be customized in future to suit the user based on their experience till that point in time and on the questionnaire the user might have filled. This feature can be seen in Figure 5.

4.4.4 *Speech based navigation* - This feature is used for navigation from one level to another (levels include Login, Menu and fear levels inside the AR application). We chose this way of implementation because cursor based navigation is not very intuitive to a new Hololens user and involves you to raise your hand and constantly keep clicking in the air. This might not only make the user uncomfortable but also increase the time to navigate between levels and the overall time to test for each user. Moreover, the HoloToolKit based speech recognition module from Microsoft makes it easier to recognize words and implement text-to-speech conversion, which helps us guide the user at different levels of app the action they need to do. This feature can be seen in Figure 10, where we ask the user to “Say Start”. We have the following Speech commands in our AR app:

4.4.4.1 “Menu”: This command works when the user wants to exit one level and come back to the Menu.

4.4.4.2 “Level <X>”: This command works on the Menu and takes the user to level X (1-5).

4.4.4.3 “Rate <X>”: This command works after the user says “Menu” to give the fear rating of one level (from 1 to 5).

4.4.4.4 “Up”: This command increases the opacity of spider on Level 4.

4.4.4.5 “Down”: This command decreases the opacity of spider on Level 4.

4.4.4.6 “Disappear”: This command renders the spider invisible on Level 4.

4.4.4.7 “Appear”: This command renders the spider visible on Level 4.

4.4.4.8 “Token”: This command displays a random token generated by the Webserver on the HoloLens app.

4.4.4.9 “Start”: This command is used for access to Menu and authentication after the token has been associated with a username.

5. TESTING AND EVALUATION:

The technical setup, integrations and modules of PhobiasCurer have been tested multiple times. Moreover, end to end testing for a dummy user has also been performed, which involves questionnaire, rating levels and viewing records online. But studies related to phobias usually take at least 3-6 months to see any considerable changes. Since we had limited time for the project, we were only able to records readings for 5 users over 2 days for 2 sessions each, which is not sufficient data to do further analysis on this. Therefore, we propose that we would continue with the experiment and report the results of the same later.

5.1 Testing

We have divided the testing into 2 parts: Eligibility and Analysis. The Eligibility portion constitutes the process of finding out whether a user is suitable for testing or not is done through a questionnaire containing a series of questions (total 38 questions) to determine whether the user is actually afraid of spiders or not. An additional control group of people not afraid of spider to remove any unnecessary bias is also considered but most of the users are assumed to be afraid of spiders. This eligibility criterion for the questionnaire is to answer at least 9 questions as YES.

After the user becomes eligible, the main experiment involves participation in several sessions over time. Each session involves viewing the different levels of the HoloLens application inside the device while a user’s heartbeat rate is monitored using Fitbit Fitness tracker band by a person sitting adjacent to the user (playing the role of a psychiatrist/assistant). The levels have been created keeping in mind the Behavior Assessment test, a common test for analyzing and rating the amount of fear experienced by an individual on a predefined scale. The user is made aware about the rules for using the device and how navigation between different levels using speech is done. In one session, the user can choose to participate in one or more levels. After each level, the user is presented a scale from 0-5 indicating how much they feared the level or how uncomfortable they felt. The ratings from each session for each level is then sent to a server where past data is stored for the particular user and they can view their progress over time: both overall and level based. At the end of the study, the user is asked to fill the same questionnaire and the questionnaire along with their progress is used for analysis and how effective the desensitization process was.

5.2 Evaluation

We are considering evaluating 2 things mainly: a) the results of the long-term study conducted on the user and b) the ease of access/usability of the solution because our aim to not only to develop an application which focuses on AR but also making it possible that desensitization and fear reduction could also be done outside of laboratories using day to day devices.

The first part involves user evaluation over time and assessing how effective is the desensitization process when carried out in an AR environment instead of real life. For analysis and evaluation, we aim to categorize the users/patients into 3 categories:

a) Somewhat fears a spider

b) Moderately fears a spider

c) Extremely fearful of spiders.

We also consider a control group of patients who are not afraid of spiders (to remove any bias in the data we collect, resulting into overfitting) and a second control group where a patient's category may be changed if they're performing well over sessions for some patients (this would help with motivating the patients and could also tell us how big a role positive reinforcement plays in handling fears). Moreover, progress of a patient is observed over sessions for the same level and for different levels. The following tasks need to be addressed for analysis:

- Carrying out category wise ANOVA for patients afraid of spiders
- Carrying out ANOVA and other statistical analyses for regular patients and 2 control groups,
- For the control group considered (not having arachnophobia), we will observe the amount false positives we see for questionnaires and experiment, the mean and standard deviation for this group. This would help us modify our questionnaire and experiment over the time
- Rate of improvements in patients versus time. We assume to see a decline in fear similar to a graph shown in the figure below:

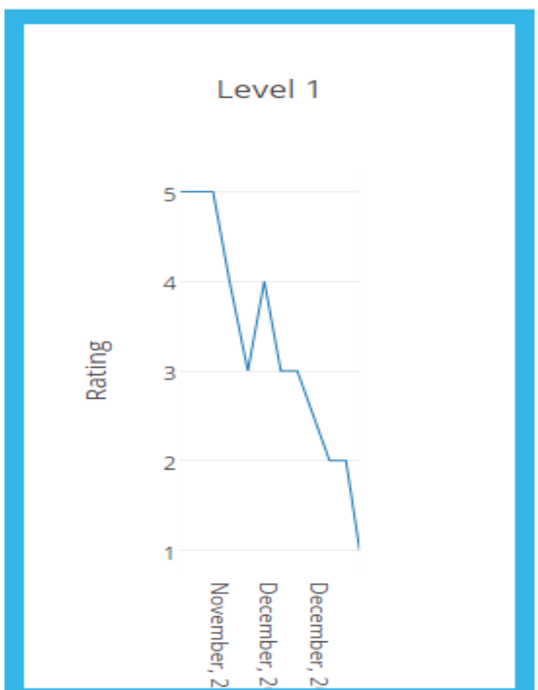

Figure 18: Suggested curve of fear of a typical patient

- Difference in number of affirmative answers in pre-assessment and post-assessment questionnaires
- Whether the experiment has led to patients answering YES for questions for which they earlier answered NO
- How does heartbeat rate correlate with self-reporting for our app
- How does the our solution fare in comparison to the previous research and treatments done to cure arachnophobia

The second part involves ease of usage and how our solution makes it convenient for the users to record their data, navigate through the application and view their progress. For this section, a rating from 1 to 10 could be assigned to each question (1 – Strongly Disagree/Negative; 10 – Strongly Agree/Positive). The following questions would be addressed:

- Is the solution implemented appropriate for the device used i.e. would a VR solution be better?
- Are the UI/Presentation layer components good?
- Does the token authentication save effort of typing on the HoloLens device?
- Is the speech based navigation in the AR app easy to use?
- Do you think the application is fast?
- What effect does the environment/ your current location have on the solution?
- Does sunlight around you affect the quality of the solution?
- How is the quality of the solution?
- What is your overall rating for the solution?

5.3 Feedback

The first user is a 21 year old male, the second a 19 year old female, the third an 18 year old male, the fourth a 22 year old female, and the fifth a 21 year old female. They were all UCSD students, but from various majors, colleges, and cultural backgrounds.

The majority of the users found the spider to not be nearly as scary as a real spider. However, one user found the spider animation through the HoloLens to be the limit of what she could handle. She experienced similar fear as to when she is confronted with a real spider, and needed longer than other patients in between trials. While we need to get a more realistic spider, it showed that using a less realistic figure could be another variable at tailoring the experience for patients. Additionally, all the patients found level 2 to be less frightening than level 1 in its current form. One common feedback from the users is that they are enthusiastic about this experience and would like to be the part of a longer study.

Figure 19: Assistant (right) noting the heartbeat rating of the patient (left) while AR app is running

Figure 20

The images on the top demonstrate how the experiment was carried out with subjects. In both the images, there is one assistant to monitor the heartbeat rate on Fitbit while the user wears the HoloLens for the AR app. Before this step, the user has already taken the pre-assessment questionnaire.

6. COLLABORATION:

6.1 Team Structure:

6.1.1 *Rishabh Singh Verma* – Took the role of Scrum Master and Project Manager. Also did the management of project plans and development process. Introduced everyone to Unity development and coding, doing a lot of coding himself. He also did research regarding existing solution of phobias. Contributed to all the parts of the report except correlation of heartrate with fear. He did the weekly documentation for all the weeks. He also worked on the basic setup of levels, animation linking and animator feature of unity to make walking of spider look realistic. He was also responsible for creating the Menu creation and Speech based navigation, Made the video for Madness Demo, Vuforia integration

6.1.2 *Himanshu Arora* – Did the initial setup of Github, Slack and other logistic softwares. Lead Developer of PhobiasCurer responsible for doing Unity development and coding. Contributed to all the parts of the report except correlation of heartrate with fear. He worked on Animator feature of Unity integrating Speech based navigation, Vuforia integration, setting up HolotoolKit within our project, assisted with animation linking. Created the entire CMS system (Backend, Frontend), created APIs for linking CMS/Web App to AR app to store user history on server.

6.1.3 *Minh Ba Vu and Matthew Wen* – Researched on concept and technique of systematic desensitization, and the correlation of heart rate with the presence of anxiety. Originally responsible for integrating fitbit hardware with HoloLens app, and looked into alternatives when real-time data streaming wasn't available. Developed most of the main features of Level 4, and fixed Level 2 to be more realistic in the HoloLens application. Also integrated HoloToolKit's text-to-speech functionality with our application by having it prompt the user with rating of each level which allows for each user to store their fear rating for the level they just experienced. Prepared the slides for Madness Demo and Midterm presentations. Contributed to the design section of the final report. Gave the Madness and Midterm demos.

6.1.4 *Justin Chang* – Helped with the Vuforia Mapping of the spider to the image. Helped fixed bug with audio repetition with Game Objects. Wasn't assigned with a general task so I helped out other group members with finishing up their tasks. Contributed to the general design of the application and what each level would do and how it related to actual phobia treatment practices. Explored other areas in project design possibilities like attempting to map the spider object to the hand but was unsuccessful.

6.1.5 *Dilraj Singh* – Researched past behavioral studies done to combat phobias, and past studies done using virtual and augmented reality. Helped with some of the HoloLens and Unity development with Minh and Matthew. Conducted user studies with 5 patients with the

HoloLens and the Fitbit. Wrote the Motivation and Background section and contributed to the Testing and Evaluation section for the final report.

6.2 Collaboration

We used Slack messenger to communicate the progress of the work. The HoloLens was shared between 2 teams, comprising of 2 members each. We felt that lack of Windows 10 with everyone and in the Multimedia lab was a constraint and the work could have been made parallel otherwise, within the team. We updated the weekly progress on the shared Google doc and received excellent feedback from the TA's on the forward direction for the project. Vish's advise to contact Danillo for Vuforia was a big help for level 5. We also met during weekend to debug the code and help each other. We did not face issue in planning the meetings and Bates hall, SGA was our common place to meet.

6.3 Problems/Issues and how they were handled:

There were a few obstacles that had stood in the team's way in terms of collaboration, both external and internal. Many of the obstacles, such as schedule conflicts and time constraints respectively, occurred either outside or inside of the course curriculum.
(1) *Conflicting Academic Schedule* - The external obstacle were each individuals' schedule during the ongoing academic quarter. At times, some of the members couldn't make it to several meetings, primarily due to their academic schedule conflicts. In response to this, the whole team had improvised a weekly routine where there were days when assigned members had to meet up to complete an assigned task. When it came to Friday, we all collaborated on the current efforts. As a result, this has brought efficiency upon the development of the project.
(2) *Time Constraints* - With eight weeks as the available time within the academic quarter, there was an enormous pressure placed upon the team for the application development. The primary issue was that the concepts needed to develop HoloLens app were completely new to every member of the team. As a result, the entire team spent a good amount of time in learning the concepts, such as developing with Microsoft HoloLens and Fitbit, which then occupied time that could be used to develop the application.
(3) *Insufficient Amount of Microsoft Hololens* - The lack of available Microsoft HoloLens has affected the development process of the application. Throughout the quarter, few members were unable to move forward with the development process, primarily due to being short on Microsoft HoloLens. Microsoft HoloLens were needed to test the developing features, but since there was a limit for the team, we needed to get together as a group to keep developing. Also, the multimedia lab doesn't support HoloLens app, which needs Windows 10 installation.

7. CONCLUSION

PhobiasCurer is an augmented reality based solution motivated by the process of systematic desensitization for curing arachnophobia. Since the beginning of this project, we have been trying to make it as close as possible to the real world experiment, keeping in mind the easy of usability by the patient coupled with minimum effort required to track their progress. Our tests with real people show that it is somewhat helpful to them, yet not realistic enough to make them feel of a real world situation. Bringing PhobiasCurer to this stage is a huge accomplishment. There were a lot of difficulties that the team had to face but we finally made it through.

8. FUTURE WORK

Our vision for this project was to demonstrate that an Augmented Reality device can help treat people with phobias. Our limited time frame of 10 weeks allowed us to create a portion of our vision. We hope to improve and work on the following aspects:

8.1 Consider VR solution for phobias:

Currently the field of view of the Microsoft HoloLens is somewhat small. It feels like you are looking out of a small window into the AR world. We plan to explore the VR devices for simulating phobias and compare the experiences across the two for a more realistic experience.

8.2 Mobile application for check-in

The solution that is implemented currently has a website that you can log into from a desktop. The ideal product would have a mobile friendly website and possibly a QR code generator so the user doesn't have to input the key that is prompted at the loading screen of the Phobias Curer app. If possible, we would create the Phobias Curer app to recognize the username spoken and upload content directly to the website database without any generation of the key.

8.3 Heartrate integration

Currently use the Fitbit as a way to log heartbeat data during the use of the HoloLens. We discovered that the Fitbit provides an API for data access, however the Fitbit could only updated every 15 minutes. We would like to have instant feedback during the treatment. Ideally we would have the users heartbeat data sent directly to our website from the fitbit. That would provide the user with access to all of their statistics through one website.

8.4 Vuforia spider projection on hand without a marker/target

Our current solution requires that we have the users hold out a piece of paper on their hand for the spider to be mapped to. Vurforia does not currently support the recognition of organic 3-D objects and we could not create a mapping to a hand. The Microsoft Hololens also cannot recognize any gestures besides bloom and clicking with the index finger so using the Hololens tools was impossible to recognize an outstretched hand. We would like to remove the paper and have the spider appear on the hand directly for a more realistic experience.

8.5 Improved quality assets

We would have liked to use a more realistic spider model and environments but unfortunately the realistic models on the Unity3D Asset Store are expensive. None of the team members knew how to generate 3D models on Unity, so we resorted to using a free spider model. A more realistic model would better simulate a spider and in the future we would replace our model with a realistic one. This also includes the spider animation variety. We are currently limited to the animation scripts that came with the model but ideally we would like the spider to have a variety of animations to seem more realistic.

8.6 Increase scope of testing

We only had the opportunity to test our product on a small number of people. In the future we would like to have the opportunity to test this on a large number of patients for more accurate feedback. We would also like to test this over a longer duration, to see how effective our phobia treatment in the long term. Since we have limited access to proper test subjects, getting a doctor to test the PhobiasCurer on some of their patients would be ideal.

8.7 The addition of multiple fears

We only had the opportunity to test our product on a small number of people. In the future we would like to have the opportunity to test this on a large number of patients for more accurate feedback. We would also like to test this over a longer duration, to see how effective our phobia treatment in the long term. Since we have limited access to proper test subjects, getting a doctor to test the PhobiasCurer on some of their patients would be ideal.

9. REFERENCES

"Systematic Desensitization -- Self-administered." Systematic Desensitization -- Self-administered. N.p., n.d. Web. 04 Dec. 2016.

Nield, David. "Neuroscientists Have Successfully Removed Specific Phobias From People's Brains." ScienceAlert. N.p., n.d. Web. 04 Dec. 2016.

Wikipedia contributors. "Fear." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 2 Dec. 2016. Web. 2 Dec. 2016.

Wikipedia contributors. "Phobia." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 22 Nov. 2016. Web. 22 Nov. 2016.

Marshall, Frank, et al. Arachnophobia. Buena Vista Home Entertainment, 1990.

Szymanski, Jeff, and William O'Donohue. "Fear of spiders questionnaire." Journal of behavior therapy and experimental psychiatry 26.1 (1995): 31-34.

Schmitz, Christopher, et al. "Physiological Response to Fear in Expected and Unexpected situations on Heart Rate, Respiration Rate and Horizontal Eye Movement." (2012).

Arntz, Arnoud, et al. "Negative beliefs of spider phobics: A psychometric evaluation of the spider phobia beliefs questionnaire." Advances in Behaviour Research and Therapy 15.4 (1993): 257-277.

Öst, Lars-Göran, Paul M. Salkovskis, and Kerstin Hellström. "One-session therapist-directed exposure vs. self-exposure in the treatment of spider phobia." Behavior Therapy 22.3 (1991): 407-422

Botella, Cristina, et al. "Treating cockroach phobia with augmented reality." Behavior Therapy 41.3 (2010): 401-413

Juan, M. Carmen, et al. "Using augmented reality to treat phobias." IEEE Computer Graphics and Applications 25.6 (2005): 31-37.

Steimer, Thierry. "The biology of fear-and anxiety-related behaviors." Dialogues in clinical neuroscience 4 (2002): 231-250.

Craske, M. G., and S. J. Rachman. "Return of fear: Perceived skill and heart□rate responsivity." British journal of clinical psychology 26.3 (1987): 187-199.

Liu, Jun, et al. "Heart rate and heart rate variability assessment identifies individual differences in fear response magnitudes to earthquake, free fall, and air puff in mice." PloS one 9.3 (2014): e93270.

Kozak, Andrea T. "Treatment of Specific Animal Phobias and the Relationship of an Opiate Antagonist to Outcome." (2003).

"Microsoft HoloLens." Wikipedia. Wikimedia Foundation, 19 June 2015. Web. 04 Dec. 2016.

McLeod, Saul. "Saul McLeod." *Simply Psychology*. N.p., 01 Jan. 1970. Web. 22 Nov. 2016. <http://www.simplypsychology.org/Systematic-Desensitisation.html>.

McLeod, Saul. "Saul McLeod." *Simply Psychology*. N.p., 01 Jan. 1970. Web. 14 Nov. 2016. <http://www.simplypsychology.org/behavioral-therapy.html>.

"Phobias - Symptoms - NHS Choices." *NHS Choices*. Department of Health, 14 Jan. 2016. Web. 04 Dec. 2016. <http://www.nhs.uk/Conditions/Phobias/Pages/Symptoms.aspx>.

Kuschyk, MD Juergen. "Cardiovascular Response to a Modern Roller Coaster Ride." *Cardiology | JAMA | The JAMA Network*. N.p., 15 Aug. 2007. Web. 20 Nov. 2016. <http://jamanetwork.com/journals/jama/fullarticle/208412>.

Appendix:
Pre and Post Assessment Questionnaire with Yes/No answers

1. Do you check the lounge for spiders before sitting down?

2. Can you deal effectively with spiders yourself when you find them?

3. Do you sometimes dream about spiders?

4. Do you ever make plans in case you come across a spider?

5. Do you sometimes look at the comers of the room for spiders?

6. Do you get other people to get rid of spiders when you find them?

7. When imagining a spider, is it always the same one or kind?

8. Do you think a lot about spiders?

9. Would you know how to cope with spiders in the bath?

10. When watching television, would you notice a spider crawling across the floor elsewhere in the room?

11. Do you sometimes use a book or a newspaper to deal with a spider?

12. Do you worry more about spiders than most people?

13. Do you feel a lot more secure if someone else is in the house, in case you come across a spider?

14. When you imagine a spider, can you see parts of it in great detail?

15. Do you check the bedroom for spiders before going to sleep?

16. When you find a spider m a room, would you avoid going in that room until someone else had removed it?

17. Do you ever find yourself thinking about spiders for no reason?

18. Would you get help if you came across a spider?

19. Do you ever lie in bed at night and listen out for spiders?

20. If you thought you saw a spider would you go for a close look?

21. Do you sometimes find it an effort to keep thoughts of spiders off your mind?

22. Would your mind be a lot easier if spiders did not exist?

23. Are you always on the lookout for spiders?

24. Do you often think about particular parts of spiders for example the fangs?

25. If you find a spider in the bath, would you, say, use a shower to wash the spider down the plughole?

26. Are you sometimes distracted by thoughts of spiders?

27. Have you a "plan for action" in case you find a spider in the kitchen?

28. Are you sometimes haunted by thoughts of spiders?

29. Do you make very certain there are not spiders around before taking a bath?

30. If you discover a spider in the room, do you leave the room straight away?

31 When watching television do you think more about the danger of there being a spider in the room than about the program?

32. When you see a spider, does it take a long time to get it out of your mind?

33. Do you sometimes sense the presence of a spider without actually seeing it?

34. Are you slightly scared to enter a room, say a bathroom, where spiders have been in the past?

35. If there is a spider in the house, are you the most likely person to find it?

36. Have you had nightmares about spiders?

37. Would you think about using a broom to deal with a spider in the kitchen?

38. Can you spot a spider out of the corner of your eye?