

Enhanced Mental Health Diagnostics: The Unity PHQ-9 Model

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Abstract—Mental Health is a crucial component of well-being of an individual, yet many people avoid seeking help even when there is a high necessity. The reasons behind avoiding help can be due to the stigma, privacy concerns and many more reasons. Our proposed approach “Enhanced Mental Health Diagnostics” allows an individual to self-assess their mental health state in a private setting using VR, this will remove the barrier of privacy concerns and social stigmas. This is a Unity 3D based application, which guides the users to explore the virtual environment. Then the individuals take the PHQ-9 questionnaire to assess their mental state. The PHQ-9 evaluation is used for screening, diagnosing, monitoring and measuring the severity of depression. The benefited individual for this application will be any individual who desires to understand the state of their mental health, the evaluation can be taken by any age group. Based on the PHQ-9 criteria, the individual has to be of age 18 or older.

Keywords—PHQ-9, Game-based PHQ-9, Mental Health Evaluation, Major Depressive Disorder, Gamified Assessment, Virtual Environments, Mental Health Diagnostics

I. INTRODUCTION

Mental Health is considered as a social stigma even in the current generation. An individual might feel uncomfortable to take an evaluation and assess their mental health due to the social stigma, or other factors like privacy concerns. It takes time for an individual to build trust and talk about mental health, it is not a common topic that is communicated very comfortably with strangers. To bridge this gap, technology can be used in various ways – one such way is through our proposed approach which is discussed further in this section.

A. Goals and Objectives

In the application we have developed, we aimed to create a user-friendly way to take a mental health assessment. The PHQ-9 evaluation is widely known to help an individual to do a self-assessment and understand their current mental health state [1]. The evaluation is conducted over a period of two weeks 0-3 item rating assessing presence of symptoms over a duration 2 weeks the PHQ-9 Scoring is shown in Table 1. Based on these scores, 0-27 point scale is observed and then the diagnosis is done. The severity is based on scores is shown in Table 2. The individual will be able to walk through the virtual environment and take the questionnaire. After taking the questionnaire, the severity is decided based on the score obtained. Hence, this application allows to accomplish taking a mental health assessment and understand the severity without compromising the privacy of the individual and makes it easier.

TABLE I. PHQ-9 SCORE

Item Rating	Assessment
0	Not at all
1	Several days
2	More than half the days
3	Nearly every day

TABLE II. INTERPRETATION OF PHQ-9 TOTAL SCORE [9]

Distribution of PHQ-9 Scores According to Depression Diagnostic Status*			
Level of Depression Severity, PHQ-9 Score	Major Depressive Disorder (N = 41) n (%)	Other Depressive Disorder (N = 65) n (%)	No Depressive Disorder (N = 474) n (%)
Minimal, 0-4	1 (2.4)	8 (12.3)	348 (73.4)
Mild, 5-9	4 (9.8)	23 (35.4)	93 (19.6)
Moderate, 10-14	8 (19.5)	17 (26.1)	23 (4.9)
Moderately severe, 15-19	14 (34.1)	14 (21.5)	8 (1.7)
Severe, 20-27	14 (34.1)	3 (4.6)	2 (0.4)

B. Modeling

The VR environment is built efficiently, considering all the factors to make navigation easier for the individual. The environment contains a park, which contains various elements like buildings around, cars, bus stop, roads. The environment is made very lively by adding fountains containing fishes, birds and butterflies flying around. The park is full with lush greenery, interactive crossing and ambient city sounds which improve the user interactivity. There are few interactive actions which can be performed like unlocking doors. All these are vital to enhance the user engagement. The individual can have a soothing experience throughout the environment. The questionnaire will be available for the individual while exploring the environment. There are different scenes which keep occurring based on the users mental health state. The environment will be changing with varying score. Finally, the results and necessary suggestions are displayed.

C. Programming

The application was built on Unity 3D platform using C# programming. Multiple C# scripts were created for different functionalities.

II. RELATED WORK

Previously, few research studies were conducted to understand how technology can be used in the domain of mental health. In 2016, Birk and Mandryk have discussed the benefits of games for the assessment of mental health [2]. By this time, researchers have already started focusing on game-based tools, which can be used to evaluate mental health severity. In 2017, Vallejo et al. conducted research where they

created a game-based assessment tool for patients with Alzheimer’s disease [3]. The results obtained in this research study showed that the assessments were user-friendly, and the patients didn’t find it extremely hard to navigate; assessments were done successfully. In 2019, Kim and Ifenthaler conducted a study where the outcomes and benefits of game-based assessments were discussed. It also discussed the past and future of this approach, concluding that game-based assessments are proven to elevate the experience of an individual while making it easy for any individual to take an assessment [4]. This paper helps us understand the importance of game-based assessments, which lead to the proposed approach of gamified assessment for mental health diagnosis. The PHQ-9 evaluation model was chosen as it is one of the well-known and most-used evaluation metrics to understand the severity of the mental health state [5]. In 2018, using PHQ-9, Khamwang, Wongwatkit, and Yachulawetkunakorn conducted a research study to simulate a game for diagnosing major depressive disorder based on PHQ-9 [6]. In their project, users are automatically diagnosed by understanding the level of Major Depressive Disorder (MDD); accordingly, guidelines for initial recovery are given. There are very few game-based assessments for PHQ-9. However, there were studies conducted, which claim that reporting of patient symptoms is critical for diagnosis and therapeutic monitoring in psychiatry like the study conducted by Torous et al. [7]. Since smartphones are handy and easy to use, researchers have considered this and asked the patients to use their personal smartphones to run the study app to monitor their symptoms. The results prove that this is a great way to keep track and monitor symptoms and look after an individual. By constant monitoring of symptoms, this project tackles the issue that depressive symptoms are a heterogeneous and constantly evolving dynamical system [8], and by keeping track of them, efficient diagnosis can be done. There are many online or application-based assessments like the ones mentioned above, which assess the individual's state of mental health and provide diagnosis – but there are very few gamified versions of these assessments. With our project, we aim to implement the game-based assessment without compromising on privacy while enhancing the user's experience by providing a very lively and interactive virtual environment.

III. IMPLEMENTATION

The implementation contains 4 main components that complete the game. These implementation steps are discussed further in this section.

A. Modelling Phase

The virtual environment elements are designed and modelled using SketchUp software. The elements like parks buildings, roads and other interactive objects. These will be used to enhance user engagement.

B. Exporting to Unity Phase

After the modelling phase, the assets are exported to Unity 3D for further development. Using these the elements, the complete virtual environment will be created.

C. Behaviors, Scripts and Functionality

After the assets are imported into Unity and basic structure of the environment is done. We use C# scripts are developed to add interactivity and functionality to the virtual environment. The scripts were created to control the player movement, interactions with NPCs, and environmental

changes based on the mental health severity, and scene transitions. The sound effects and background music are added through scripts. This way all the C# scripts are used to improve the functionality and the overall experience of the game.

D. User Interaction

The player will interact through the mobile application, which uses a First Person Controller, this allows the users to navigate in the virtual environment using the on-screen controls. The various interface elements like heads-up display, menu buttons, and pause options are displayed on the screen – these will facilitate user interaction and enhance usability.

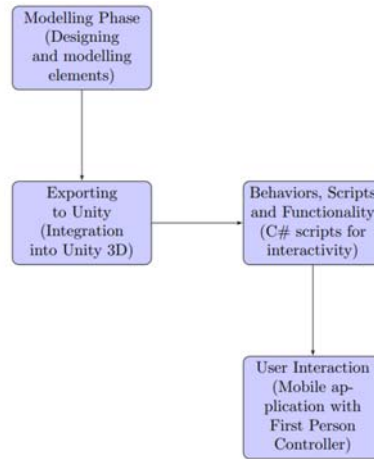


Figure 1 Overview of Implementation Architecture

IV. FUNCTIONALITY

A. Vision

We have used the online resource to obtain few assets which were required. Few assets were also modified according to our objectives using SketchUp software. Overall, the textures and 3D models which were used include .fbx files and .skp files. Figure.2. shows the summary of a few main textures and models that were used to build the virtual environment and Figure.3. shows the Textures of the Behavioral Health Center building with some other props in the environment.



Figure 2 Virtual Environment with trees, rocks and other props



Figure 3 Behavioral Health Center

B. Sound

For sound we have implemented a constant background noise, nature sounds in the park, and chirping of birds when they fly closer to the player. Apart from these, the footsteps sounds of the player are added, these will be changing based on the environment. In few scenes, thunderstorms and rain are visible and heard, during such scenes the footsteps sounds of the player are modified. When the player is walking in such scenes, the splashing water sound is heard. There are 5 different scenes for 5 levels of severity, and each scene has sounds modified according to them. Furthermore, There is background audio for each and every scene, and also added the Videos on tv screen with filtered audio which makes the user immersed in the Virtual World. Figure.4. shows the Audio manager which was applied to a specific scene with the music source and the music file and the music source contains the Audio Source component to control the volume and other settings of the background music.

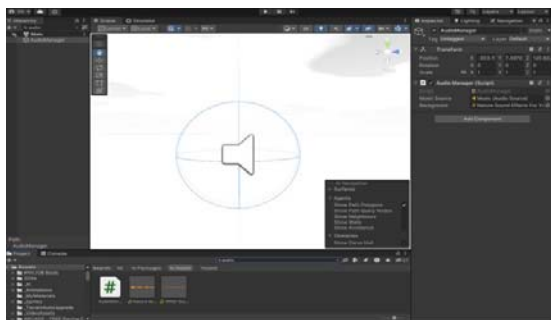


Figure 4 Audio Manager

C. Animation

There are simulated people throughout the environment, there is behavioral animation added to these characters. Vehicles will be moving along a path, these animations will stop and move according to the traffic signs. More animations in the park include fountain particle system, rain and thunders which will appear based on severity. There are birds and butterflies which will be moving around in the environment to make it look more lively. More environmental changes are made as the scenes keep changing. Figures 5&6 show the animation of water in the water fountain inside Unity Park and the animations of thunderstorms with rain.



Figure 5 Animation of the Water Fountain in the Unity Park



Figure 6 Animation of Rain and thunderstorms

D. Interactivity

The player can interact in the virtual environment in many ways. The questionnaire itself is made to be very interactive. The player can interact with the environment by playing, pausing, and Stopping the Videos on the Wall through buttons. The player can explore the environment and perform actions like opening doors and many more. Figure 7. Shows the opening or closing of the door of the Behavioral Health Center building by using the Key button. Figure 8. Shows the video control buttons implemented inside the virtual environment and the player can control the video using those buttons. Overall, the interactivity of the player with the virtual environment played a very vital role in achieving enhanced user experience.

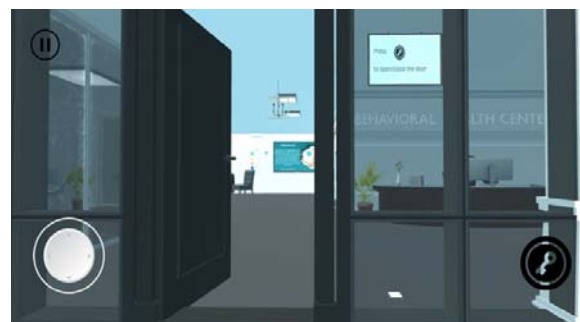


Figure 7 Opening/Closing the door of the Behavioral health center using the Key button

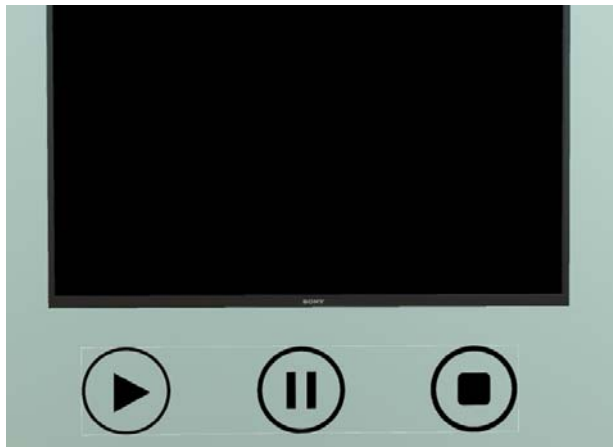


Figure 8 Play, Pause and Stop buttons to control the Television

E. Characters/Avatars

The player is built in first perspective, hence no avatar is visible on screen for the player. However, there are behaviour simulated characters throughout the environment. There are characters in the park working out, sitting on a bench and moving around. Inside the building, there is a receptionist at the entrance and few people around moving in their animated behaviour. Also added the AI Avatars which will be moving inside the environment with different animations. These animated characters allow the scene to look more interactive and the user can have an enhanced user experience. Figure.9. shows the NPC (Non-Player Character) running on the footpath and Figure 10. shows the NPCs inside the Behavioral Health Center.



Figure 9 Non-Player Characters with Animations

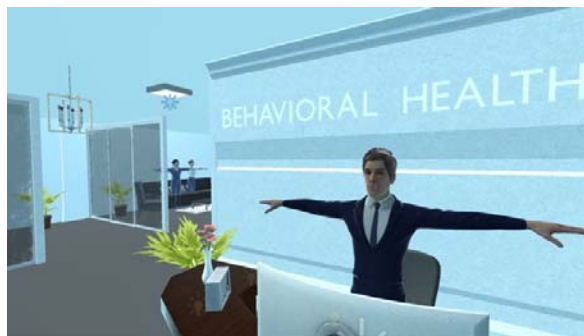


Figure 10 Non-Player Characters inside Behavioral Health Center

F. Sensors

There are few sensors included in the project. When the birds get closer to the player, the birds chirping is heard more vividly. When the car is moving around, it is timed in a way

that it stops at the traffic sign. The scenes are changed based on the severity score, as the severity score is increasing – the scenes are changing from normal scene to a very cloudy scene and then to a thunderstorm scene. Figure.11. shows the vehicles are controlled by traffic signals.



Figure 11 Traffic lights controlling the flow of traffic using time Sensors

G. Player

The players uses First Person Controller. This is a mobile application, the controls are setup to improve ease of use. Figure 12 shows the controls on screen of the application and the First Person view of our player inside the Unity Park. The mobile can be hand held horizontally and using thumbs the player can navigate around the virtual environment with the help of controls provided.



Figure 12 View of our First-Person Controller

H. AI Implementation

For AI implementation we utilized the Navmesh component in unity which will help the avatars in Pathfinding and we applied the Navmesh surface for the entire scene and also verified that the Navmesh surface is properly baked in the environment by placing the AI avatars. We have used a simple C# script for their movements and also the Animator for Avatar movements. In total we added 8 AI pathfinding Avatars and even though the Avatars are on the same way they will give the way for the other avatars based on their priority levels in the environment. Figure 13. Shows the NPC with Navmesh Agent component walking inside the Unity Park of our virtual environment. Figure 14. Shows the Navmesh surface of our entire virtual environment which makes the AI Avatars walk inside the environment without any collisions and we added 8 NPCs with Navmesh AI component and each Avatar performs different animations.



Figure 13 Non-Player Character with Navmesh Agent walking in the Unity Park

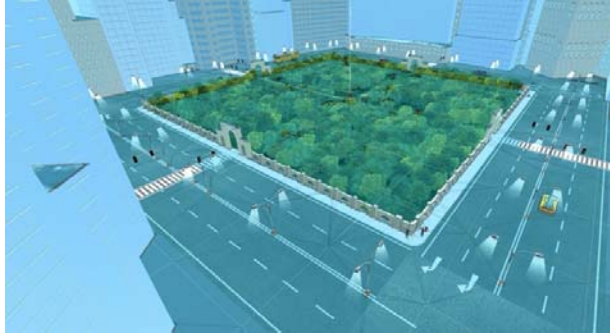


Figure 14 Navmesh Surface Component on our Virtual Environment

I. Interface Elements

The game consists of heads-up display, menu, pause buttons and more such interface elements. Figure 15&16. Shows the basic interface elements that were implemented in the game. The main menu of this game consists of Play, Instructions and Quit. The basic options of Resume, Home, and Pause are added to each scene which helps the user to come back to the main menu. By giving these options to the player, we aim to increase the usability of the game. The assessment can be paused if there is a need, and the player can return back to it whenever. The player controls are also displayed on the screen, the player will be using these to navigate around the virtual environment.



Figure 15 Main Menu



Figure 16 Pause Panel with Home and Resume Buttons

J. Integrations and Requirements

The application is built for a smartphone. The only hardware requirement is the smartphone. This game application is developed on Unity and built for a smartphone. We have used Mixamo to get proper character animations.

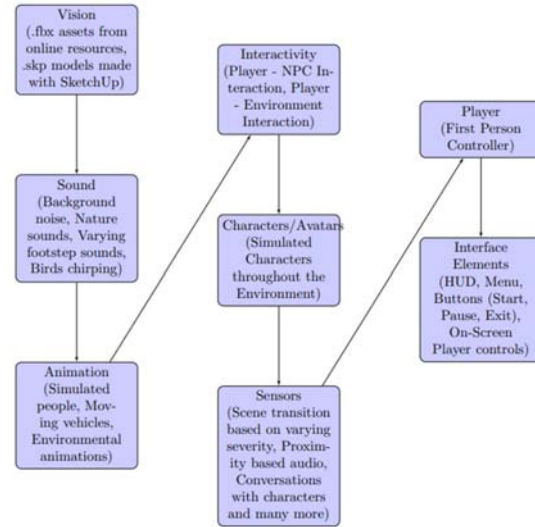


Figure 17 Overview of Functionalities

V. CONCLUSION

The project we have implemented allows an individual to take a self-assessment easily and diagnosis is given based on the severity. In the future, we will make the environment more user friendly. Apart from that, we plan to add other mental health assessments like Beck's Depression Inventory (BDI-II), Generalized Anxiety Disorder 7-item scale (GAD-7), State-Trait Anxiety Inventory (STAI) and Patient Reported Outcomes Measurement Information System (PROMIS). These all assessments can be used to understand and evaluate an individual's risk. Currently we are not storing the data, the assessment is done and instantly results are provided. Later on, we plan to keep a track of the assessment results – this allows the patient to understand their mental health levels based on the scores over a longer period of time. The environment is created to cater the needs of a patient, and will be modified over time to adjust to the changing needs. In the future, we will explore the idea of adding VR into this game, to enable using VR Headset and making the user experience even more better. We will also look into the possibility of conducting group sessions where individuals can join as a

group, each patient will have their own avatar. They can meet in the virtual environment and be able to form a virtual support group. The endless possibilities to combine game-based assessments with evolving technology create a path for innovative approaches to mental health care and support.

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