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The effects of virtual reality on mental health software user satisfaction and retention

William Hooten
University of Tennessee at Chattanooga, garrett-hooten@utc.edu

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William Garrett Hooten

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Mina Sartipi
PhD, Professor of Computer Science
Thesis Director

Roland Howell
Professor of Computer Science
Department Examiner

Jill Shelton
PhD, Professor of Psychology
Psychology Department Examiner

Abstract

Mental health issues have become increasingly important in today's society. With that being said, researchers and consumers are looking for new ways to manage and treat mental health using new technologies in labs and the consumer space. This innovation has led to the presence of mobile self-help mental health applications, applications for peoples' phones that are used to manage symptoms of mental health problems, such as depression and anxiety, track goals, meditate, and more. However, mobile mental health applications, and mobile applications in general, have a problem concerning user satisfaction and overall user retention – studies have shown that 95% of mobile apps downloaded are abandoned by users within a month (Gu et al., 2022). Virtual reality is a relatively new and blossoming technology that provides the illusion of being physically present in virtual environments, opening an entirely new realm of possibilities across many industries. Virtual reality has already been shown to be effective in treating mental health due to its immersive nature, yet few applications exist for mental health self-help in VR. This thesis aims to answer the question of whether an immersive VR application for consumer VR systems, such as the Meta Quest 2, can have a positive effect on user satisfaction and potential user retention when compared to mobile applications.

Dedicated to Taylor Wells, for inspiring me to keep pushing when life gets challenging.

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Chapter 1: INTRODUCTION

Problem Statement

As technology becomes more accessible in daily life, new solutions to existing problems are created every day. Mental health is one of these issues, as increases in mental health concerns such as depression and anxiety leave many looking for solutions that are more accessible to them personally. This has led to the creation of self-help mental health software— a way for users to treat their mental health issues with or without the help of a professional, on their own time through means of a mobile application, website, or other interactive program. These self-help applications have been shown to be effective, with users reporting decreases in negative thoughts and better self-efficacy as long as they are using the programs (Orosa-Duarte, 2021). The issue with these applications is that they rely entirely on repeated, constant use by the user to maintain their effect, which is a challenge many mobile apps face, as users eventually stop using the apps over time, losing their benefits (McCloud, 2020). While many tactics have been tried to increase user retention, this thesis aims to see if putting mental health self-help applications in a fully immersive virtual reality experience can increase user motivation to continue to return to the app.

Define the Problem

While mobile apps have been shown to be effective in treating mental health issues such as depression and anxiety, they have an underlying issue in user retention. Similar to mobile games, users tend to stop using these apps after just a few weeks or months, losing the benefits that the app provides (Verto Analytics, 2016; McCloud, 2020). Many tactics have been developed to keep users engaged in these apps, such as daily login rewards, yet the issue remains. Virtual reality (VR) is a growing technology that offers a completely new, immersive

medium for software of all kinds, including mental health apps. VR has previously been shown to be effective in treating mental health problems, through means such as virtual reality exposure therapy (VRET), but these studies occurred before VR technology had been made widely available to consumers (Maples-Keller, 2017). Today, with consumer VR systems like the Meta Quest 2 and the Valve Index becoming increasingly popular, there is a lack of mental health software for this new medium compared to mobile platforms. This thesis aims to question if a mental health application, designed similarly to mobile applications currently available, in a fully immersive virtual reality experience will be more interesting to users and increase overall user retention and satisfaction.

Background Information

Mobile mental health applications have been shown to be effective in treating symptoms of mental issues, such as depression and anxiety, but have issues maintaining their users past the first few weeks or months (McCloud, 2020). Meanwhile, VR technology has become much more accessible to the average consumer in the last four years than it has ever been. VR not only opens the door for a new age of media consumption, but also a whole new virtual world that continues to see innovation in many industries; from office work to medical training, VR is likely on its way to permanently change how people work and play. VR has already been proven to be effective in treating some mental issues, like phobias, through means of VRET, which is the process of gradually increasing exposure to a triggering stimulus in a safe and controlled environment (Maples-Keller, 2017). The process of exposure therapy lends itself well to VR due to its reliance on visual and auditory experience, which are the primary stimuli of current-generation VR technology. Some researchers have dabbled in the idea of using VR to treat

depression and general anxiety disorder (GAD), but the research behind the topic is lacking overall, and the few applications that aim to serve this purpose have yet to leave the laboratory.

Possible Treatments or Solutions

Plenty of self-help apps already exist for managing symptoms of depression and GAD in the form of websites, mobile apps, or even games. Many of these are structured very similarly, beginning with a daily mood check-in and a series of breathing and relaxing exercises that help the user manage their stressors and emotions. While VR treatments for depression and anxiety have been studied, the overall research and development of these applications is lacking and there is yet to be an application accessible for consumer VR systems. Most VR software that has been studied has been proprietary software developed specifically for the study it's used in, and never sees life outside of the study. It has not yet been studied whether being in virtual reality influences user retention or satisfaction compared to existing mental health apps.

Purpose of the Paper

Many mental health self-help applications already exist, and while they are effective, they face a challenge in user retention. Many strategies have been tried to increase user retention across mobile apps, like daily login bonuses and objectives, but mental health apps still struggle with maintaining their users' attention.

Virtual reality is a new and evolving technology that is becoming increasingly accessible and popular with the public. It offers a fully immersive experience that other platforms cannot offer and has found uses in a variety of industries — healthcare, training, entertainment, etc. — and has also been researched in mental health applications. Studies have shown that virtual reality can be as effective as — if not more so than — other 2D applications and self-guided

programs in treating mental issues (Maples-Keller, 2017). There remain some problems with these studies, however: they are often fairly old, occurring before the VR "boom" in 2016 that began the mass consumer adoption of VR technology, using proprietary software and hardware, and there have been no studies on the effects VR has on user satisfaction and retention compared to mobile or desktop software.

The aim of this thesis is to see the effects on user satisfaction and potential user retention that VR has on existing, proven-to-work methods employed in mobile mental health applications today. Since there is no existing VR mental health application, Unity 3D and Meta's Quest development tools will be used to create a free application for the Meta Quest 2. The application will be designed so that it will be easy for the user to navigate through without needing the help of a professional therapist and will feature exercises derived from studies on what practices work in other applications of the same purpose so that the VR application can be effective in treatment.

Chapter 2: REVIEW OF LITERATURE

Validation of Mental Health Self-Help Applications

The need for mental health services is at record highs — as of 2015, nearly one quarter of U.S. adults suffer from a mental disorder and half of the same adult population will experience a mental disorder at some point in their life (Comer, 2015). Comer notes in his study that despite the prominent mental health issues in the country, access to resources is inadequate given that only 40% of Americans with mental disorders receive treatment within a year.

As technology improves and becomes more accessible, people have begun to create and use self-help programs on their personal devices to treat their mental issues. Self-help mental health applications have been around for years and come in many shapes and sizes; however, this thesis focuses on mobile applications and their effectiveness when compared to virtual reality (VR) applications. Mobile self-help apps have been shown to be effective in the past – in a study on Pacifica, a mobile app focusing on treating symptoms of stress, anxiety, and depression, the authors found significant reductions in depressive and anxious thoughts and behaviors while also reporting an increase in perceived self-efficacy of the users (Moberg et al., 2019).

Just like the mental health crisis, mobile self-help apps aren't restricted to adults only. Children are increasingly exposed to technology, whether through schools or by parents, for a variety of reasons ranging from entertainment to education to parental distraction (Weekly et al., 2018). Since children are becoming acquainted with technology so young, some pediatric health institutions have begun to use mindfulness apps similar to those that adults use for mental health to calm down and distract children present with chronic pain and undergoing treatments. A 2018 study revealed that these mobile apps were helpful in helping children manage their symptoms

and treatments, and even urges pediatric institutions to begin considering mobile apps as official parts of their treatment plans (Weekly et al., 2018). While the authors suggest increasing use of mobile apps in pediatric treatments, they also noticed positive effects on the parents of the children as well, particularly in apps that offer creative exercises, like drawing calming images in collaboration with their children.

Validation of Virtual Reality as a Mental Health Medium

Virtual Reality (VR) was first examined in the mental health space in the early 1990s, when psychologists began to use VR with exposure therapy (Maples-Keller et al., 2017). These studies focused on the treatment of acrophobia, or the irrational fear of heights, which lends itself well to the audio-visual experience that VR systems provide, leading the researchers to conclude that VR was an effective medium for treating issues similar to acrophobia. Since then, research into VR exposure therapy has grown drastically, using VR to treat a wide array of phobias and anxiety disorders by placing users in virtual environments specifically designed for them to face their feared stimulus and overcome their feelings (Maples-Keller et al., 2017). A similar study from the University of Oxford agrees with Maples-Keller et al.; in their own review of VR studies concerning mental health before 2017 they found that the "methodological quality of studies was generally low," but that "VR has the potential to transform the assessment, understanding, and treatment of mental health problems" and "could greatly increase access to psychological therapies" (Freeman et al., 2017). This study highlights VR's strengths in treating anxiety-based mental health issues, like post-traumatic stress disorder, paranoia from attack from persecutory delusions, or even learning how to resist the urge to continue drinking for alcoholics. The authors state that some of the times VR can help most is when a stressful simulation can be simulated and the participant can be coached through or practice taking the correct actions

(Freeman et al., 2017). VR provides a medium that, while the participants know it is fake, tricks their mind and bodies to act as if it were real. Since participants know it's fake, they are much more likely to be willing to face difficult situations in VR and prepare themselves before facing them in real life (Freeman et al., 2017).

VR can be used in mental health outside of anxiety-based disorders, as well. In a 2016 study published by Cambridge University, the researchers used VR to encourage self-compassion in participants experiencing overwhelming self-critical thoughts or diagnosed with depression. The experiment they conducted was quite unique compared to previously discussed methods regarding exposure therapy; they used the illusion of body ownership in VR, where a virtual body replaces the participant's real body and tricks the participant to feel as if they possess the virtual body, to place the participants in an adult body and also in a crying child's body. Participants would first act as the adult consoling the crying child, giving it positive affirmations. After that they were placed into the body of the crying child and recordings of their movements and audio from their session as the adult were replayed to them from the perspective of the child. The authors found that self-criticism was "significantly decreased" after participants heard their own affirmations coming from a third person perspective (Falconer et al., 2016). While the methods the application in this thesis differ greatly from the body-ownership illusion used in this study, this is an interesting experiment that furthers the validity of VR as a medium for managing different types of mental health issues.

A more recent example of how VR has been used to treat or manage mental health symptoms is from the recent COVID-19 pandemic. VR was used heavily in training doctors and medical staff for treating patients, but the mental health application with COVID-19 lies within the patients: VR was used to manage and distract from psychosomatic disturbances as well as

manage pain and guide patients through physical therapy (Singh et al., 2020). This use of VR "ultimately reduces recovery time and enhances the patient's satisfaction," providing benefits to the mental health of patients affected by the pandemic (Singh et al., 2020).

Mobile Apps, User Retention, and User Satisfaction

The issue of user retention in mobile apps is larger than just the conversation about mental health self-help software. According to Verto Analytics, mobile games make up 57% of mobile app usage as a whole – and yet, after 30 days after downloading, only 10-20% of an game's userbase still regularly return to the game. While mental health software isn't a video game, this is staggering for the majority share of mobile app usage to result in such low user retention, and this is likely shared across many different app genres. Many mobile mental health apps face the same fate, even using tactics like gamification and daily rewards to entice users to return regularly. Another study presents dire numbers concerning user retention for mobile apps, stating that approximately 20% of all apps downloaded are used just once, and if an app is used more than once, 55% of these users do not use them on a regular basis. The study also found that around 95% of downloaded mobile apps are abandoned by users within a month (Gu et al, 2022).

Low user retention for mobile apps has been the focus of several studies as developers look for ways to continue engagement in their apps. In the study by Gu et al. referenced earlier, the researchers experimented with implementing crowdsourcing methods into the Catchphrase mobile game. These crowdsourcing methods used were allowing users to submit their own content within the game, like phrases or words, to be accessed by other users for play in their own sessions. This experiment showed significant improvement in user retention when users were given the option to submit content and use other's submitted content – the risk of a user ending their session improved by approximately 11% and the chance the user would completely

abandon the app was lowered around 14% (Gu et al, 2022). This must be done with balance, however; the researchers noted that overexposure to user/community-based content was possible, and that this overexposure could result in faster burn-out of players, and that users who created content for the game could feel unrewarded if their submissions did not gather sufficient playtime, creating burn-out for the creators as well. The study concluded that apps can benefit significantly from a well-designed system that incentivizes users to create and play user-made content, without overexposing or underexposing either type of user (Gu et al, 2022).

Regarding mobile mental health apps specifically – the story is much the same. Many mental health apps that claim to have a good user experience have a wide range of retention rates, from as low as 35% to 100% retention rates (Ng et al., 2022). The issue with this measurement, however, is the lack of standardization of what qualifies as "engagement" towards user retention and satisfaction, the authors of "User Engagement in Mental Health Apps" note. The authors describe a discrepancy between the claimed high rates of user satisfaction and retention of these mobile apps and the actual low levels of engagement of these apps in the real world – a discrepancy they say is "harmful – not only to the field, where progress is impeded, but also to patients, who may not know which app to trust" (Ng et al., 2022). While mobile mental health apps can be effective in their treatment of mental issues, some have issues with properly reporting user satisfaction and many have problems retaining users over time, which is often required for users to maintain the benefits of the app's treatment.

Chapter 3: RESEARCH APPROACH AND PROCEDURES

Purpose/Research

The purpose of this thesis is to construct a free, user-focused mental health application for the Meta Quest 2 and other consumer virtual reality systems, and to gauge how user satisfaction and potential user retention for the VR application compare to mobile mental health applications. It has already been shown that both mobile mental health apps and virtual reality systems can be effective in helping users manage their mental health symptoms. For example the Pacifica mobile mental health app was shown to significantly reduce depressive and anxious thoughts and increase perceived self-efficacy in participants (Moberg, 2019); and virtual reality has been shown to be effective through means of exposure therapy and said to "have the potential to transform the assessment, understanding, and treatment of mental health problems" (Freeman, 2017). However, there is the problem of user retention in mobile apps. Across all types of mobile applications, with around 20% of apps downloaded being used just once, and if used more than once, only around 55% of the users are "regular" users (Gu et al., 2022).

Virtual reality is a new immersive 3D medium that has the potential to improve user satisfaction and retention when compared to 2D software experiences found on computers, tablets, and phones. Some businesses are already starting to incorporate virtual reality options into their business models, such as car dealerships and stores incorporating virtual reality systems to help users visualize products or cars/car interiors before purchasing. This leads to a higher chance that a customer will purchase the product and the chance that they will return to the business with the VR solution for their next purchase (Brunner & Wolfartsberger, 2020). In his article, Brunner suggests that more businesses begin incorporating virtual reality into their

businesses to increase customer retention. Thus, this thesis aims to get early data on the potential levels of user satisfaction and potential user retention of mental health apps in virtual reality.

Development Approach

For development, the Unity 3D engine was used to create the application. Unity 3D is a robust cross-platform video game engine that is known for its ability to easily build one product across multiple platforms and architectures. Unity 3D has also been the primary target for innovation within virtual reality software and development, with large companies such as Meta and Valve pushing constant updates to their Unity packages (pre-packaged software development kits, application programming interfaces) to encourage developers to push the experiences on their virtual reality platforms further. Unity 3D also recently added support for OpenXR – a standard, unified API for creating augmented reality, virtual reality, and mixed reality applications across PC, console, and mobile/standalone platforms – into the engine to work natively with their other cross-platform tools. This thesis utilized the XR Toolkit developed by Unity to build the app to Windows platforms with Oculus and SteamVR support as well as the Meta Quest 2, which is based on the Android mobile operating system. The Unity Asset Store, a marketplace for user-made Unity packages, was used in development to reduce development time by using premade art assets for the environments in the application. All of the design of the application and programming was done by the primary researcher.

Preliminary Ideas

The original concept for the application was to adapt the flow of mobile mental health apps to virtual reality for the most direct comparison of the mobile interface versus a virtual reality experience for user satisfaction and retention. The virtual reality application's design was

primarily based on the apps Amaha (formerly named InnerHour) and Daylio. These applications are designed to manage anxiety and depression through means of daily mood logging, regular goal tracking and motivation, and guided breathing and meditation exercises. Likewise, the virtual reality application was to follow this same model.

Upon opening the application, users were to complete a mood survey that asks the following: to rate their current mood (1-5 Likert scale illustrated with images of facial expressions), to select 3 recent emotions they have experienced from a list, and to select recent activities they have done (cleaning, family time, meditation, etc…) from a list. Similar introductory surveys are found in both Amaha and Daylio as part of their daily log-in routine. After completing this survey, the main menu was displayed with the option of breathing exercises, the goal-tracking flower field, a menu to enter goals to track, and a randomly selected inspirational quote to motivate the user.

In the main menu there was an “Edit goals” button that lead the user to a page displaying all entered goals. If the user had not entered any goals, a goal titled “Enter goals to track” was automatically added to the list. There was a “+” button in the top right corner of the menu, and when pressed a large keyboard was displayed in front of the user with 3D keys, and mallets were placed in the user’s virtual hands. The user could use these mallets to type on the large keys and hit “Enter” to submit their goal to the list. This “Edit goals” button could also be found below the button to enter the goal flower field, as a reminder to update the tracked goals.

In the breathing exercise, the user was placed on a platform in a winter mountains environment with calming wind noises playing around them. Then the user selected their desired duration of the exercise, from one to ten minutes. After selecting the duration of the exercise, the user clicked “Begin” and a green circle appeared with text prompts giving instructions on how to

follow the breathing animations performed by the green circle. The circle rotated through growing and shrinking animations for three actions: inhale (circle grows large), hold breath (circle retains large size), and exhale (circle shrinks to original size). After completing one cycle of breathing with instruction, the instruction prompts were replaced with randomly-selected motivational phrases, such as “Release your stresses with each exhale.” After the duration of the exercise, the user then chose whether to start another deep breathing exercise or return to the home menu.

In the goal flower field, the user was placed in a sunny meadow filled with flowers, and for every goal they have entered into the application, there was a large pink flower with their entered goal floating over top of it. There was also a vase in front of the user. For every goal that the user had completed, they may use their hand controllers or the laser selector to pick the flowers and put them in the vase. The flowers inside the vase were marked as “complete,” while the flowers remaining in the field were “incomplete.” This design was to provide a more interactive and rewarding experience for completing goals to increase motivation for users to complete their goals. Also in the flower field was a menu button labeled “View Your Friends’ Progress,” where users could see the vases and bouquets that their friends they have connected to had made, with each flower representing a goal they have completed. The individual goals were private, any user could only see the number of flowers collected by their friends. There were also buttons for each friend to send encouragement to complete their goals if the user felt they were behind by looking at their bouquet. Finally, there was a “Home” button always present in the flower field for the user to return to the main menu at any time.

Chapter 4: RESEARCH SUMMARY AND PRODUCT DEVELOPMENT

Research Summary

As stated before in this thesis, mobile self-help applications have been shown to be effective in the treatment and management of mental health issues like anxiety and depression (Moberg, 2019). These applications show great potential in increasing accessibility for mental health support and services across many age groups and demographics – some researchers are even encouraging pediatric care to begin implementing mental health mobile applications into their treatment (Weekly, 2018). The problem mobile mental health applications (and mobile applications in general) have, is user retention. Of all mobile applications downloaded onto a device, 20% are used just once, and 55% of users do not use them on a regular basis (Gu et al, 2022). Some mental health applications boast high user retention rates, anywhere in the range of 35-100%, other studies have found that the methods used to determine user retention and satisfaction for mobile software is often not accurate to the claims being made (Ng et al., 2022). Mobile mental health applications often find the same issues with user retention that a majority of mobile applications share.

Virtual reality (VR) is a new technology that is just beginning to breach into the mainstream consumer market. VR is an entirely new, completely immersive medium that brings new possibilities to a wide range of industries, mental health applications included. Like mobile self-help applications, VR has been shown to be effective in the mental health space as well. VR exposure therapy is a method growing in popularity due to VR's ability to simulate stressing stimuli for patients with anxiety disorders and irrational fears. The feeling of virtual-body-ownership that VR provides has been used in treating depression, and VR is even being used in the midst of the COVID-19 pandemic in managing psychosomatic disturbances and assisting in

physical therapy (Falconer, 2016; Maples-Keller, 2017; Singh, 2020). This thesis asks the question, as VR continues to increase in popularity among consumers, would an immersive VR self-help application designed similarly to a mobile self-help application help improve user satisfaction and, potentially, user retention.

Prototype Development

Development began in June of 2022 with the collection of the first assets and libraries needed to begin working on the app. While Meta provides their own SDK for their VR systems, it would be beneficial for this app to be cross-platform across the Windows 10/11 PC-based VR ecosystem and the standalone Meta Quest ecosystem, for testing during development and overall product accessibility alike. The choice was made to use Unity's XR Interaction Toolkit – a Unity package built on the emerging OpenXR standard for cross-platform development of VR, AR (augmented reality), and MR (mixed reality) games and applications. This way, any headset or system that supports the OpenXR standard would be able to run the application once a build is made for the appropriate platform. In Unity, a template project was made for learning the basics of VR development and using the XR Interaction toolkit. The application has many menus the user must interact with by design, so the first thing that was created was a basic menu system. A basic Unity canvas set to render in the worldspace was created with two pages and a button to switch between the two. Where on a flat-screen application this button would natively work with a tap on a touchscreen or a click from a mouse, there is no native way in Unity for a VR device to interface with the menus. Conveniently the XR Toolkit includes a component called the "XR Ray Interactor," that is set up to interact with worldspace canvases. After creating some small green spheres to represent the hand controllers and attaching this ray interactor to the right hand sphere, the right hand index trigger was set to be the menu select button, and the user was able to

switch between these two demo pages by pointing the laser provided by the XR Ray interactor at the button and pulling the trigger. While this demonstration worked in the Unity editor, it hadn't been tested on the Meta Quest's native hardware, nor did the developer have any experience building applications for the Quest's hardware. Fortunately, the process of building a Unity application to the Meta Quest is as simple as switching the application platform to Android and selecting "Oculus Quest" (Oculus is still the name used in Meta's development documentation) as the target device in the XR Settings pane. After changing these settings, the test application was successfully built and run on the Meta Quest 2. It should be noted that while these default build settings worked, they were far from ideal as even in a blank environment with one menu, the resolution and performance of the app was low, and that optimizations would be needed for the final product. However, this test application was enough to begin working on the first iteration of the actual application.

First Iteration of the Main Menu

Since the developer lacks experience in 3D Modelling and art creation, it was decided to use premade art assets for the design of main menu environment, which was decided to be in a living room. The only suitable free-to-use living room that was found was a very high-detail model of a living room used for interior design. After downloading this model, it was apparent that while a desktop PC would be able to handle running this environment in VR, the mobile hardware of the Meta Quest 2 would not be able to perform well with this model. This was confirmed when testing a build of the app that only contained a scene where the user was placed in this living room model – the Meta Quest 2 could only run the app at a nauseating 15-20 frames per second (the target framerate for VR applications is often 72 or 90 frames per second). The model was opened in Blender 3D, a free, open-source 3D art application, and edited using

the “decimate” modifier to drastically reduce the complexity of the models in the scene. Many small objects in the scene had around 10,000 polygons alone – far too detailed for an app on mobile hardware. In their best efforts, the developer reduced the size of these models to around 1,000-3,000 polygons each as any further reduction changed the model beyond recognition. Another problem with the model was that there were no textures or materials provided, so all the furniture in the room was left as a white, plastic-like material generated by default in Unity. Fixing the living room graphics was not a priority at the time since the actual main menu needed to be created. To get the main menu in a working state fast, the test menu from the demonstration application was copied to this project and the two pages were changed. The first page was to be the “Main Menu” page that would display a wealth of information about the application and provide access to the activities the application contained. The second page was to contain a list of the activities and buttons to begin each one. To get the app in its first working state as soon as possible, a single “Activities” button was added to the main first page, and a single “Breathing Exercise" button was added to the second activities page. The final product of this first iteration of main menu was a bland, white, plastic-looking living room with a main menu very similar to the demonstration application, except the “Breathing Exercise” button loaded the user into a blank scene that was to become the breathing exercise, rather than sending them back to the first page of the menu.

Development of the Breathing Exercise

The initial idea for the breathing exercise was to create an experience similar to the guided breathing exercises found in mobile mental health applications like Amaha, except utilize the immersive aspect of VR to place the user in a calming environment that would assist in removing distractions during the exercise and helping the user focus. To accomplish this vision,

the concept of the breathing exercise became one where the user was placed in an isolated, snowy mountain range with the sounds of the wind playing around them, and a light green circle that grew and shrunk to represent inhaling and exhaling in a 4-4-4 pattern. The 4-4-4 pattern is where the user inhales slowly for four seconds, holds that breath for four seconds, then exhales slowly over four seconds; this method has been shown to provide physical benefits like better quality of sleep and improved heart health in addition to reducing anxiety and depression (*Box Breathing*, 2022).

Beginning development of this exercise, a blank scene was created with nothing but the XR Camera Rig (The object representing the VR Headset and connected controllers) and a sphere. Then a custom script was added to the sphere that gradually changed the scale of the sphere in Grow() and Shrink() functions. These functions used public variables that can be changed directly in the Unity editor, such as timeToGrow, maxScale, and minScale. The changing of the scale of the sphere was done using Lerp(), which returns a value between two points on a linear scale, called once per frame until the sphere had reached its desired size. The problem with this implementation was that the length of time that it took for the sphere to change size was dependent on the framerate the application was running in, and at first the length of time that was required for the sphere to change its scale was inconsistent. It was attempted to get around this issue using Unity's Time.deltaTime variable, which stores the time in seconds since the last frame, in the Lerp() calculation to make the sphere grow consistently; however the implementation was hard to use when setting up the full script for the breathing exercise and still not perfectly consistent for the desired 4-4-4 breathing pattern.

Since the script-based modification of the sphere was not stable enough for use in the actual exercise, it was decided to use animations to achieve the desired effect. The sphere and the

script component were deleted from the scene and 3 very thin cylinders were created and stacked on each other to create a more visually appealing circle. Using Unity's animation tool, animations were created for growing and shrinking the circle such that the layers changed independently of one another to create a smoother, more dynamic visual experience than a single circle growing and shrinking. These animation clips were saved as assets in the project so they could be called in scripts later. Then an empty GameObject and corresponding script component was created, called BreathingExerciseHandler, that accessed the circle object and its animations. The script used coroutines, which are state-machine-style functions that can be paused and resumed by yielding, to play the animations for the circle when desired through the Animator.Play() function for the Animator component on the circle. Then the circle could grow and shrink consistently in a 4-4-4 pattern.

The next part of the breathing exercise to create was the text prompts that guide users through the exercise. To do this, a worldspace canvas was created similar to the main menu canvas and a single, centered Text object with text shading was placed in the center of the user's view. Animations were created for the smooth fade in and fade out of text, to add to the calming environment. Then in the BreathingExerciseHandler's script, the sequence of introductory messages and corresponding animations was programmed to play every time that the breathing exercise was started. After a short guide on how to follow the circle's animations with breaths, a coroutine began that repeatedly played the breath in, hold, and breath out animations for the circle as well as displaying randomly-selected motivational quotes from a pre-determined list in front of the user. This exercise originally lasted for only a minute, but was changed later in development to have a menu with a drop-down selection of one to ten minutes for the exercise to

run. After the exercise is complete, the user is presented with this menu again to either begin another breathing exercise or return to the main menu of the application.

To create the mountain environment, a pack of pre-made snowy mountain models was downloaded from the Unity Asset Store; these models were distributed around the space that the exercise takes place in. Royalty-free ambient mountain wind was found and downloaded from Pixabay and added as a sound source in the scene. A platform near the top of the mountains was added and the XR Camera Rig, breathing circle, and canvas were moved on this platform to give the user the feeling of being up high among the mountains rather than at their feet. To cover the clipping of the mountain models at the base of the platform, a free fog image was downloaded and used with Unity's particle system to create a fog effect around the base of the mountains.

First Iteration of the Flower Field

The concept behind the flower field is a more interactive, more motivating goal tracker than those found on mobile apps. On a mobile app with goal tracking, users typically enter goals they want to complete and check them off a list as they complete them. While this setup is simple to use, when thinking about how to use VR to make goal tracking more immersive and interactive, the idea was created that rather than checking off an item on a list for every goal completed, the user gets to visit a full flower field environment and gets to pick a flower for every goal completed, growing their bouquet larger as they complete their goals. This concept would hopefully motivate users to complete their goals with the incentive of visiting the flower field and picking flowers, and having a visual reminder of their goal progress throughout their desired time period.

Initially the flower field was going to be created from scratch by placing some 2D textures of flowers across a plane that had a grass texture, but since the developer was unable to find suitable individual flower textures to use, a pre-made flower field asset was downloaded from the Unity Asset Store, along with a sunny skybox to use with the field. Placing an XR Camera Rig and a canvas like the main menu and breathing exercise provided the base for the activity. The canvas initially contained two buttons: “View/Edit Goals”, and “View Your Friends Progress.” In the “View/Edit Goals” screen, it was decided that for demonstration purposes, there would be four predetermined goals for users to mark as complete and pick flowers for. These goals were simple, such as “Make my bed,” “Study for exam,” etc... These items in the goal list contained a Text object displaying the goal and a button next to them that would mark them as complete and spawn a flower for that goal to be picked and put in a vase. This design of the goal tracking would be heavily changed in future implementations of the activity.

To differentiate the pickable goal flowers from the decorative flowers in the field, a distinct 3D model of a flower was downloaded from Sketchfab and colored to be pink with a green stem in Unity. A XR Grabbable component was added to the flower so that, when spawned in the world, the user can either physically move their controller over the flower stem or point the XR Ray Interactor at the stem of the flower and hold the “Grab” button on the controller to pick it up, and release to drop it. Four empty GameObjects were created as spawn points for these flowers, and for every button clicked marking a goal as complete, a flower was spawned at one of these locations. For the vase, no suitable model was found to be downloaded from a third party, so a custom model was created in Blender and colored white in Unity. Originally, the flowers were going to be placed in the vase with physics, but due to time constraints, it was not possible to get the physics for the vase behaving properly for a good user experience. Rather,

several XR Socket Interactors were placed inside the vase. These invisible socket interactors detect when an XR Interactable Object (e.g. a flower) "collides" with them, and if the user "drops" the object inside of the socket, the object snaps into a proper place and orientation. This was much easier than implementing physics to hold the flowers upright and easier for the end user to use.

The "View Your Friends' Progress" page consists of a list of friends the user has connected to on the app and vases containing flowers representing the goals each friend has completed. To preserve privacy, no details about specific goals are shared with friends, only the size of the bouquet is shared. There is also a button to send an encouraging message to friends whom the user thinks may be underperforming in their goals. This is to provide a social aspect to the applications and provide an outlet for users to engage with and help out on each other's mental health journeys without encroaching too far into one's personal privacy. Unfortunately, due to time constraints, the implementation of this feature as of writing this thesis is purely for demonstration only, and there is no actual connection between users of the app.

Redesign of the Main Menu and Goal System

Upon completing the first iteration of the flower field, attention was turned to the lackluster state of the main menu: a blank, poorly lit white room with two buttons to launch either the breathing exercise or the flower field. A new design for the main menu was created to mirror the experience of apps like Amaha and Daylio. First, there was a Likert scale for users to select how they are currently feeling, choosing from 5 clipart emotion images, from a red frowning face to a green smiling face. Then the user is presented with a list of emotions, such as ashamed, confident, and content, and instructed to pick 3 emotions they have felt recently. After that, the user is asked to log recent activities from a generalized list, such as family time,

shopping, social media, etc… Once they select their recent activities, they arrive at the main menu, now fit with a randomly selected motivational quote, a larger “Activities” button, a preview of the user’s current goals, and a button to edit those goals. On the activities page, the buttons for the breathing exercise and flower field have updated custom graphics that better represent the activities: the breathing exercise button has mountain art on a blue background with a circle in front, and the flower field button has art of a flower field on a lighter blue background. There is also another button to edit goals below the flower field button, to act as a final reminder to update goals as they are a critical part of the flower field experience.

With this redesign was a new goals system. As stated in the section on the first iteration of the flower field, the goal tracking implementation at this point was purely demonstrative and not functional as a goal tracker. With this redesign of the main menu, it was decided that an actual goal tracking system must be implemented. To achieve this, there must be a way to create and store goals and their complete state that is persistent through application shutdown. The randomly selected motivational quote on the main menu was, in some ways, a test of how Unity handles reading and writing to a file across platforms. In that case the text file is loaded as a TextAsset in the scene and read through a series of for loops, storing the quotes and authors in arrays and randomly selecting one to display on the main menu. This works for read-only cases, but it’s not easily suitable for writing back to the file. To enable writing goals to a file in storage, the unity Application.PersistentDataPath location was used. Application.PersistentDataPath is a useful variable Unity provides that points to the application’s file storage location for the current platform, making it effortless to port I/O operations across platforms. A GoalHandler script was created to manage goals and their status, starting with the loadGoalsToList() function, that looks in Application.PersistentDataPath for a file called “goals.txt.” If the file is found, a C#

StreamReader is used to read the file line by line. The goals.txt file is formatted in pairs of lines, the first line contains the text for the goal, and the second line contains a Boolean value for the goal's complete status. Once these values are loaded into the list, the file is closed. If no goals.txt is found, the GoalHandler generates a new one with one pre-entered goal: "Enter some goals to track," with a false completion status.

On the edit goals page, the current list of goals loaded from the GoalHandler is displayed with a "-" button by each goal to delete them. Pressing this button removes the goal and its completion status from the list stored in GoalHandler. There is also a "+" button in the top right of the edit goals page, which initially spawned a new worldspace canvas displaying a keyboard that the user would interface with the same way that they interface with the other menus, by pointing the XR Ray from their right controller and pulling the trigger to press the keys. This, however, was found to be hard to use in testing, so the canvas keyboard was replaced with a 3D VR keyboard downloaded from the asset store. This keyboard works by spawning several 3D buttons for the keys in front of the user, and placing mallets on their controllers, and letting the user physically drum the keys with the ends of the mallets to type. Once the user pressed the "Enter" key, the GoalHandler took the text they input and stored it in its internal list and created a false completion status for the goal, and the 3D keyboard was removed from the scene. The "+" button could be pressed as many times as desired to enter multiple goals.

To save goals back to the file for persistent storage, an OnDestroy() function was created that used C# StreamWriters to overwrite the present "goals.txt" with an updated list of goals and completion statuses. The OnDestroy() function automatically gets called by all objects in a scene in Unity whenever a GameObject is about to be unloaded from memory, whether it is from a new scene loading or the application shutting down. Initially, to optimize the read/write operations of

the application, the DontDestroyOnLoad property that carries one instance of an object between scene loads was going to be used to allow the flower field activity to access the same instance of the GoalHandler, but it proved more challenging than originally thought to get new objects to access an object from a completely different scene. Fortunately, there is no noticeable performance penalty for the relatively small read/write operations of the GoalHandler, so it was suitable to simply destroy the main menu GoalHandler, saving all the current goals to the file, and creating a new GoalHandler in the flower field to access the updated file of user-input goals.

The next task in the main menu redesign was to replace the low-performing, blank white living room with a more visually appealing and more geometrically optimized setting. Rather than looking for a complete living room model, a low-poly home furniture model pack was downloaded off the Unity Asset Store and imported into the project. This pack included the models, textures, and materials for several pieces of common home furniture, like couches, coffee tables, and lamps. A custom room was made of planes for the walls, ceiling, and floor, and one of the wood materials from the furniture pack was applied to each. The room was furnished with models from this pack and a sound source was added to a radio on the cabinet facing the user. A royalty-free calming ambience track was downloaded from YouTube and played from the radio in the scene to set the tone for the application.

Second Iteration of the Flower Field

Since the original flower field was created with a fake goal system initially, it had to be massively redesigned to use the new GoalHandler and access real user-input goals. Adding a GoalHandler to the scene took care of loading the goals and having them accessible to the FlowerFieldEventSystem, and the current goal menu in the flower field was no longer needed so it was deleted. Rather than having the flowers spawn when the “Complete” button is clicked in

the flower field menu, it was changed so that when the scene loads, the FlowerFieldEventSystem looks for every goal with a false completion status and spawns a flower for it. It was also changed so that when the flower for a goal is placed in one of the sockets in the vase, the completion status is set to true for that goal. Conversely, once a flower exits the vase, the completion status is set to false. In addition to adding real goal tracking functionality to the application, the integration of the flower field with the GoalHandler made for a much faster and easier to use method for goal tracking compared to the fake implementation.

Final Optimizations

To begin testing the application, a build for the Meta Quest 2 was needed as currently it is the most popular and most accessible VR headset on the market. In Unity, the platform for the project was switched to Android, and the texture compression was switched to ASTC, or Adaptive Scalable Texture Compression, which is Meta's official recommendation for texture compression on Quest. Since the Quest platform does not support user-selectable render resolution, the MainMenuEventSystem script was edited to change XRSettings.eyeTextureResolutionScale to 2.5 times the original resolution, if the current platform is Android. In the build settings of the application, the anti-aliasing was set to MSAA 4x to improve render quality and the scripting backend was changed from Mono (C#) to IL2CPP, which converts all of the C# scripts to compiled C++ code for extra application performance.

Chapter 5: TESTING, RESULTS, AND ANALYSIS

Testing Design and Procedures

An entrance and exit survey would be used to gauge participants' previous experience with mobile mental health applications and VR, their current psychological state, their expectations for the VR application, and their experience with the VR application. In order to gather data on participants' psychological states before and after using the application, both the entrance and exit survey contain a Positive and Negative Affect Schedule (PANAS) questionnaire, asking the participants to rate their current feelings of a given emotion (e.g. excitement, anger, sadness) on a scale from one to five; one being not having experienced the emotion recently or regularly and five being frequently or recently experiencing the emotion.

The entrance survey contains questions about how frequently, if at all, participants use mobile mental health applications. Some of these questions are, "How often do you use a mobile app or website for managing mental health," answered on a one to five scale, and "what aspects of the apps successfully help you manage your mental health?" There are also questions about participants' previous experiences with virtual reality, whether they own a VR system, and how likely they think they would be to use a VR mental health application if they did have a VR system.

The exit survey contains the same PANAS questionnaire to gather information about what, if any, emotions in the participants changed after using the VR app. After the PANAS questionnaire, the next part of the exit survey asks users to rate their experience with the VR app, with questions such as "how satisfied are you with the virtual reality app," and "how helpful do you think that the app, or one like it, could be in treating mental health?"

Testing procedure consisted of verbally asking the participant about their experience with mobile mental health applications and VR experience, instructing the participant on how to take the entrance and exit surveys such that they would not be able to be identified by their responses, demonstrating how to use the Meta Quest and interface with the application, and reassuring them that if they needed assistance at any time or needed to withdraw from the study that they could simply ask the present researcher. Once the participant had taken the entrance survey, they then put on the Quest headset and began using the application. The participant's view was mirrored such that the researcher could observe what they were doing for the purpose of guiding them through the application when they needed assistance. After being guided through all activities of the application, the headset was removed, and the participant took the exit survey. Once the exit survey was completed, the study was complete. The Quest headset and controllers were regularly sanitized with disinfectants in between each use.

Results and Analysis

With a sample size of 30 participants (n=30), the results found may provide significant data to the conversation regarding VR in the mental health space. Full, unedited results from the surveys will be published on the application's GitHub repository and made accessible with this thesis. Changes in the average levels of emotions before and after using the VR app is given below on a scale from one to five, where one is least frequent/intense feeling of a given emotion, and five is the most frequent/intense feeling of a given emotion.

Feeling	**Average Likert Value Before VR App**	**Average Likert Value After VR App**
Interest	3.3	4.5

Distress	2.9	1.7
Excitement	3.2	3.9
Upset	2.9	1.4
Strong	3.0	3.7
Guilty	2.3	1.3
Scared	2.3	1.3
Hostile	1.9	1.2
Enthusiastic	3.0	3.9
Proud	3.1	3.5
Irritable	3.2	1.3
Alert	3.6	2.8
Ashamed	1.9	1.4
Inspired	2.8	3.7
Nervous	3.3	1.8
Determined	3.6	3.7
Attentive	3.2	3.7
Jittery	2.9	1.7
Active	2.7	2.8
Afraid	2.3	1.3

Overall, there is a noticeable trend for an increase in positive emotions after using the VR application and a reduction in negative emotions after using the VR application. On a scale of one to five, one being never/not frequently at all and five being very often, participants reported average usage of mobile mental health apps of 1.6. On a similar scale of one to five, participants

reported an average score of 2.2 for satisfaction of the mobile applications they have used. Some aspects of mobile mental health applications participants reported enjoying are distraction from problems, reminder to breathe/relax, being easy to navigate, journaling/keeping track of mental health, and meditation. Some aspects of mobile mental health applications that participants reported they did not enjoy, or that could be done better, are relying on distraction rather than actual treatment of mental health, repetitive activities, no motivation to log in daily, price, and losing interest in goal tracking and check lists. Some of the applications participants have used consist of Finch, Headspace, and Daylio (which was used as a model for the VR application). 63.3% of participants had never used VR before, and there were no consistent expectations for the VR application other than that it will "look realistic," "probably be a neat experience," and "will be hard to use." On a scale of one to five, from least likely to very likely, participants showed an average score of 3 for how likely they think they would be to regularly use a VR mental health application before trying the application for the study.

After using the VR mental health application, feedback towards the VR and the mental health application tested greatly improved. As stated before, there was an increase in positive emotions and a decrease in negative emotions after using the VR application. Where before the app participants, on average, showed a score of three out of five for how likely they would be to use a VR mental health app regularly, after participants used the VR application this average increased to 4.3. On a similar scale of one to five, from not helpful at all to very helpful respectively, when asked about how helpful participants thought this VR application or one similar to it would be in treating their mental health, participants gave an average score of 4.3. Similarly, the score for satisfaction with the VR application out of five was 4.3. Participants reported enjoying the music and sound effects of the application, feeling as if they were "really

there" in the mountains and flower field, and being completely immersed in a less distracting, calming environment. Participants particularly enjoyed the aspect of picking flowers to track their goals, with one participant stating that, "picking flowers made the goals much more attainable, because they were concrete," and another that, "physically being able to display your completed goals seemed like it would be very helpful, more so than any pre-scripted website could do." However, there were some complaints about the VR application – some of which were fixed or altered throughout the testing period with newer versions of the application. Some complaints were graphical issues, such as flickering in the breathing exercise, music choice, difficulty in picking up flowers, lack of customization options, and bugs/difficulty using the first iteration of the keyboard for entering goals. The complaints about the keyboard were addressed in a revision of the application during testing, going from a standard keyboard that worked exactly like the menus for the rest of the application to a 3D keyboard where the user physically typed on the keys with mallets. Once this change was implemented complaints about the keyboard were eliminated completely, and similarly complaints about the music were eliminated after a change in an application revision. By far the number one complaint about the application – being received in twelve out of thirty responses – was that participants wanted more activities to complete in the application. One participant wrote, "I liked it and wanted to keep going," and several responses asked for "more activities."

Chapter 6: CONCLUSIONS AND FURTHER RESEARCH

The results from this study show that VR has an amazing potential that has yet to be fully realized for treating mental health, especially when compared to mobile mental health applications. With a significant reduction in negative feelings and increase in positive feelings after using the VR application, this study can add to the overall conversation about VR's effectiveness in treating mental health. Originally this thesis asked the question of whether a VR self-help mental health application could improve on the user satisfaction and potential user retention of mobile self-help mental health applications, which are often plagued by low user satisfaction and even lower user retention. Overall, the increase in enjoyment and perceived usefulness of the VR application by participants provides a strong argument for VR being able to improve user satisfaction and potentially user retention. This study, however, isn't perfect – many aspects of this thesis were severely limited by time. With just a year to complete all preliminary research, development of the VR application, and testing of the VR application, it is impossible to gather concrete data on actual user retention, as the testing of that question in particular would take a minimum of six months, if not longer, to properly gauge user's regular usage of the VR application over time. Similarly, the quality of the application itself could be greatly improved with more time for development. With more time, several of the bugs that participants encountered could be fixed, more activities added, and the overall user experience refined further than the application tested now, which is essentially in alpha state. What this thesis does provide is a starting point for further research. The results of this thesis show that the assumptions made in the hypothesis are true – mobile mental health apps appear to be having a problem with user satisfaction, with a score of 2.2 out of 5 for satisfaction from this study's participants, and a larger problem with user retention, with participants of the study showing a

score of 1.6 out of 5 for how often they use the mobile mental health applications they have downloaded. Comparatively, participants reported an average score of 4.3 out of 5 for satisfaction of the VR application, and an average score of 4.3 out of 5 for how likely they thought they would be to use the VR application, or one like it, regularly if they had a VR system. It appears that the immersive experience of VR is beneficial to the enjoyment of the activities found in mental health software, since the activities of the VR application were modeled directly after a suite of mobile applications.

However, as stated before, the measurement of user retention from this thesis must be studied further to get any concrete answers to how VR affects long-term VR usage. While the participants seemed to have a rather optimistic view on how often they think they would use the VR application, the truth of the matter is that currently mobile platforms are far more accessible by design than any VR system. One participant noted that with a mobile mental health application, they can pull out their phone at any time and engage with mental health activities. With this VR application, even if the software is running on low-cost standalone hardware, it still requires the user to ensure that they have space to move around the in VR and ensure that their space is safe for them to inhabit without any spatial awareness, since VR headsets isolate users from the real world in most cases. VR is still in its infancy, so these accessibility aspects may change as the technology evolves, but these are limitations of current VR technology. What is shown in this thesis is that VR shows very promising results for providing more engaging and enjoyable mental health experiences for mental health software than mobile platforms, and that the participants of this study believe that they would like to use VR mental health applications regularly. Hopefully this thesis can inspire further research and development in VR mental health applications to not only further see how VR actually affects long-term user retention with its

limitations, but to also use VR to create more polished and effective mental health software and experiences for consumers that mobile platforms simply do not have the technology to match.

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