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TITLE: EnVRMent: Investigating Experience in a Virtual User-Composed Environment

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ABSTRACT

EnVRMent: Investigating Experience in a Virtual User-Composed Environment

Matthew Key

Virtual Reality is a technology that has long held society’s interest, but has only recently began to reach a critical mass of everyday consumers. The idea of modern VR can be traced back decades, but because of the limitations of the technology (both hardware and software), we are only now exploring its potential. At present, VR can be used for tele-surgery, PTSD therapy, social training, professional meetings, conferences, and much more. It is no longer just an expensive gimmick to go on a momentary field trip; it is a tool, and as with the automobile, personal computer, and smartphone, it will only evolve as more and more adopt and utilize it in various ways. It can provide a three dimensional interface where only two dimensions were previously possible. It can allow us to express ourselves to one another in new ways regardless of the distance between individuals. It has astronomical potential, but with this potential we must first understand what makes it adoptable and attractive to the average consumer.

The interaction with technology is often times the bottleneck through which the public either adopts or abandons that technology. The goal of this project is to explore user immerision and emotion during a VR experience centered around creating a virtual world. We also aimed to explore if the naturality of the user interface had any effect on user experience. Very limited user testing was available, however a small user group conducted in depth testing and feedback. While our sample size is small, the users were able to test the system and show that there is a positive correlation between influence on the virtual environment and a positive user emotional experience (immersion, empowerment, etc.), along with a few unexpected emotions (anxiety).
We present the system developed, the user study, and proposed extensions for fruitful directions for this work by which a future project may continue the study.
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The world has long held an interest in virtual reality, seeing it as a gateway into limitless worlds of our own creation. From early tools like the ViewMaster, flight simulators, the Sensorama, and all the way up through the development that has lead to modern head-mounted VR, we have been intrigued by not only the novelty fun that immersive images offer but the practical application of the technology. This extends outside the reaches of entertainment, into areas like tourism, automotive, military, and of course, healthcare. One thing that has held the technology back as a whole is its lack of mass adoption. Mass adoption is often a lead drive in a technology, and understandably so - investors are unlikely to put funding into projects with little public interest, and businesses are unlikely to devote valuable resources to the development of something often seen as a “fad” and unsustainable.

1.1 VR Today

Modern HMD’s (Head Mounted Devices) specifically regained public interest starting in 2012 with the Oculus Rift headset. Earning nearly ten times the amount of their initial $250,000 goal on Kickstarter [30], the Rift blazed a trail that left an important message: people want to experience what VR has to offer. The public already recognizes the potential in the technology, and this caught the interest of social media goliath Facebook. In 2014, Facebook bought Oculus for $2 billion. Mark Zuckerberg is quoted as stating, “Mobile is the platform of today, and now we’re also getting
ready for the platforms of tomorrow. Oculus has the chance to create the most social platform ever, and change the way we work, play and communicate” [46].

Soon after, other notable companies began to develop and market their own HMDs, including Valve and HTC (Vive) [39] and Sony (PSVR) [19]. In 2015, Google announced the Google Cardboard at their I/O conference, showing that VR can be done easily, cheaply at merely $25, and be exactly as accessible as a smartphone (as it used the smartphone itself as the display) [37]. This then spurred the Mobile VR movement, bringing companies like Samsung in with their Gear VR headset, with even more capability [45] at a still affordable cost of $99, often bundling it and its controller with new Samsung phone purchases and pre-orders [24]. This, plus the clunkiness of HMDs, pushed companies like Oculus to develop standalone devices that did not require a bulky wire connected to a $1000+ computer. Enter devices like Oculus Go [40] and Oculus Quest [41], the latter of which recently received a second version release after an explosively successful lifespan [31]. These standalone headsets offer the middle-ground between an immersive PC-based HMD and the cheaper mobile HMDs that often suffered from limited processing power, leading to the eventual end of popular smartphone-based VR (for now).

Hardware limitations aside, VR is often used in many fields as an immersive aid. The United States military has used it both in training simulations and as a therapy to treat trauma as far back as 1997 [49][36][11]. VR has also been used in the medical field of course. Notable applications include surgery training, planning, and even remote telesurgery [22]. One interesting case of VR in the medical field was VR Vaccine, a 2018 project in Brazil where VR was used to distract children from the pain of an injection to make the experience not only tolerable, but enjoyable [34]. Other similar applications exist for purposes like distraction during burn treatment of severely injured burn victims [27].
1.2 User Perception

It is within this realm that we hoped to aim this application - for it not just to serve as an insight into what effects user experience in VR, but given they are immersed, can this serve as a viable therapeutic? In recent years, depression and anxiety has become an increasingly prevalent issue not just in adolescents, but in the general population. The CDC in a 2016 report stated, “from 1999 through 2014, the age-adjusted suicide rate in the United States increased 24%” [13]. The CDC reported that during June of this year, a staggering 40% of adults reported mental health issues [14]. Non-medication based treatments for depression and anxiety are often therapy of some sort, ranging from the typical verbal therapy to more exploratory fields like art therapy, where an individual may gain from simply expressing themselves through artistic projects. This provides a more comforting experience to some because the person being treated does not have to worry about immediate reactions from another person; they simply paint and express themselves through creation [38]. With applications like this merged with ideas such as VR Vaccine in mind, we created an experience that gauged emotional reaction to the ability to control the environment. Does the experience make the user feel calm, relaxed, and in control? Does it provide some sort of momentary break or relief from the real world? These are the questions we hope to answer.

1.3 Contributions

In this project, our aim is to better understand the role that influence over environment plays in user immersion and emotional response. In the same realm as art therapy, we believe giving someone full control over their surroundings will provide them with a feeling of empowerment and control, in a world which they may feel
they have none. We also believe understanding this link will provide useful insight into not just the potentially increased immersion of such an effect, but also fulfilling the expectation of control one has when in a virtual environment. To that end, we furthermore determine if naturality of the user interface plays into this link; does the user feel more empowered and connected to their environment if the interface is more organic, or do they prefer the straightforwardness of a typical button-based interface?

To answer these questions, we developed two versions of a single Virtual Reality application dubbed “Planet Painter.” In the experience, users can influence their environment using something that often correlates to emotion: color. As discussed in [35], people often subconsciously associate color with certain objects from their own past experience, and further associate the emotion behind the color to the emotion of that past experience. Therefore, we hypothesize that a person will choose colors most pleasing to themselves, and will create an environment they most enjoy. In the base version of this application, players are presented with a control panel with which they can select different colors. In the experimental version, players can use a brush and palette to actually paint a planetoid presented in front of them, representative of the world they stand on. The most common color on this planetoid determines the environment type, and second most common color determines detail object color. For example, a mostly Blue planet with many yellow spots will immerse the user in an underwater world with yellowish corals. This is meant to be the more “natural” UI, intended to connect the player with their environment moreso than the button layout.

After players are satisfied with the experience, they fill out a survey asking about their experience. Questions include inquiries about emotional reactions to the environment, physical reactions, and any changes they would make if they were to create this application themselves. The latter of these is to gain better insight into their
feelings of empowerment over the experience. Full versions of all surveys can be found at the end of this paper.

Due to limited testing, we cannot at this time make statistically significant assumptions. We did however test six individuals, then followed up with a deeper post-experience interview to get a more comprehensive look into what they felt during the experience. We also began the discussion of what an emotionally immersive application may look like, using their experience with our application as a starting point. In the end we conclude that it does appear that control over one’s environment in VR space has a positive effect on immersion, and further work would do well to capitalize on creating features that provide increased control to the user.
Chapter 2

BACKGROUND

2.1 History of VR

While Virtual Reality may seem to some like a concept only now making its way from science fiction to science fact, the technology has been around much longer. Some trace the original “blueprint” of VR to Ivan Sutherland’s 1965 essay, “The Ultimate Display,” in which he remarks the capabilities a user has with regards to input on a digital screen. Although displays were much simpler at the time, with dot-matrix displays and vector graphics being cutting-edge, he wrote that ideally, computers could not only produce area-engulfing images, but that they should also be able to know what virtual objects a user is pointing to, as well as what part of that object, and so on. He discusses technologies that eventually do come to fruition, albeit sixty years later, such as eye tracking, voice recognition, and accelerometers. However, his essay brings all these ideas into one uniform technology by which a computer can realistically simulate any object, bound by our laws of physics or not, and that we could interact with them. He finishes with a statement that is truly representative of the drive to create ever-immersive VR, “With appropriate programming such a display could literally be the Wonderland into which Alice walked” [47].

In World War II, the United States purchased and utilized over 10,000 “Link Trainers,” which were the first commercial flight simulators, shown in Figure 2.1. These enabled training in a safe but semi-realistic environment, improving the skills of over half a million pilots [2]. Another notable stepping stone in VR was Morton Heilig’s Sensorama, an arcade-style cabinet that included not only an immersive dis-
Figure 2.1: Link Trainer at Freeman Field, Seymour, Indiana during WWII [3]

Figure 2.2: Ivan Sutherland’s HMD, The Sword of Damocles [26]
play but a vibrating chair, fans, and scent generators [2]. Eighteen years later in 1968, thanks to the aforementioned Ivan Sutherland and his student Bob Sproull, the world received its first computer-controlled (as opposed to camera-controlled) VR headset, the Sword of Damocles, named so because it had to be mounted into the ceiling and the user had to be strapped in (Figure 2.2). While the U.S. military continued to experiment with HMDs mostly for pilot training [20], consumer VR continued to lean into the entertainment sector during the early 90s. These included the 1991 Virtuality arcade machines, the 1993 Sega VR HMD for the Sega Genesis, and finally, Nintendo’s VirtualBoy HMD [9]. Each of these however, eventually failed and fell from the public eye due to their limitations, both physical and digital. Computer graphics have substantially improved over the last twenty or thirty years, though it is only in the last ten to fifteen years that consumer hardware has become lightweight enough and graphics have become robust and fast enough for a VR experience to be truly immersive [44].

2.2 Development Environment

2.2.1 Oculus Rift S

The Oculus Rift S (Figure 2.3) is Oculus’s most recent product in their Rift line of HMDs. It is PC-based, requiring a connection to a moderately powerful PC. It features a single fast-switch 2560x1440 LCD display with a refresh rate of 80Hz. Because of this single screen as opposed to dual-screens (one for each eye), the Rift S only features software inter-pupillary distance adjustment, not physical. It has a 115-degree field of view, and an attached halo-style adjustable headband. It typically includes two Oculus controllers, both of which are utilized in this experiment. Head and hand tracking are accomplished via inside-out technology [29], which uses on-headset cam-
eras to track the environment and translate this to head and hand movement. This is opposed to (until recently) more popular outside-in tracking technology, which uses cameras placed around the environment to track the devices.

2.2.2 Unity

There are a few ways to build out a virtual reality application - one may build from scratch using OpenGL, but as with building anything from scratch one might spend a significant amount of time “reinventing the wheel,” per se. Most modern VR applications are built using game engines, most likely either Unity or Unreal Engine. When choosing between the two, the important factors to consider are the required level of graphical fidelity and the desired development environment complexity. While Unreal Engine is typically praised over Unity for its ability to produce more realistic and robust graphics, Unity is more user-friendly. The level of detail it provides is sufficient for the first iteration of this project. Future iterations however, may benefit from a full conversion to Unreal Engine because of its advantage over Unity in graphical fidelity as mentioned before. However, studies have shown graphical
realism is not always tied to immersion as one might think [12]. This is also discussed in chapter 6.

2.2.3 SteamVR SDK

At the start of this project, Unity had support for a number of virtual reality plugins, including SteamVR, MagicLeap, and WindowsXR through Khronos Group’s OpenXR system (Figure 2.4). Of these, we opted to use SteamVR. Significant progress was made through the implementation process, but in January of 2020 Unity updated their environment to instead support their own more modular and newer Unity XR plugin, which was built to support all previously supported plugins, while unifying them under the same framework (Figure 2.5) [23][48]. However, SteamVR’s parent company, Valve, had not yet developed a version of their plugin compatible with OpenVR, effectively deprecating SteamVR until it is updated to be compatible. Development options here were either to restart using Unity XR or find a workaround within Unity. We predicted the latter to save considerable time. Version rollback was then achieved via Unity’s “Unity Hub,” which allows for the specification of version
Figure 2.5: Unity’s new XR API provides a proprietary SDK to interface with others, and includes the features listed within the subsystem. [6]
at every instance of startup. This application was then continued under Unity version 2019.3.5f1.

The SteamVR plugin handles a few key things for making a virtual reality application in Unity. The first of these is the conversion from a single camera into a VR headset camera. This preset handles head tracking and motion for any popular VR headset. SteamVR also provides a SteamVR_RenderModel component through which various Unity “gameobjects” can be mapped to the different poses of two connected controllers. SteamVR coincidingly supplies an input system shown in Figure 2.6, by which controller input customization is made much easier, and is even sometimes used in non-development environments (in tandem with Valve’s Steam game launcher). Finally, SteamVR also provides an Interaction System, through which multiple actions can be performed such as object interaction, teleportation, and interaction with Unity UI elements.
Chapter 3

RELATED WORKS

3.1 Virtual Reality in Therapy

Though the technology has not been widely accessible until fairly recently, various forms of therapy have utilized virtual reality precisely for their immersion factor. In one study in particular, VR was used as a distracting tool during burn treatments. These treatments can be extremely painful, and medications to ease pain often include steroids and opiates, both of which an individual can build up a tolerance to and become dependent on, with varying side effects once the medication stops. VR proved to be the perfect remedy to this, with patients showing both verbally and via MRI scans to be in less pain when distracted by virtual worlds in the VR HMD [25]. During burn treatment, patients were equipped with a VR headset that would display a cool, snowy environment around them (“SnowWorld”) wherein they could interact with different objects and characters in the environment by throwing snowballs at them. This is similar to the previously mentioned VR Vaccine project [34] seen in Figure 3.1, where children took part in a narrative story, saving their “realm” by attaching a special armor piece to their shoulder while in the real world, they received the injection in the same location. However, while VR can be a useful tool to treat physical pain, it can of course be used for emotional distress and even cognitive disorders.

On the side of cognitive disabilities, a study took place in 2016 which sought to assist children with diagnosed ASD (Autism Spectrum Disorder) with “emotion recognition, social attribution, attention and executive function” [16]. They did so
Figure 3.1: VR Vaccine: a VR experience in which children play through a fantasy story, ending with them putting on a magical artifact (taking the vaccine) and “saving the realm” [34]

by interacting with some virtual representations of common environments, such as a school cafeteria, classroom, and playground. In the end, the children were shown to have significant improvements in both social cognition and analogical reasoning [16]. In another VR social study, participants were either placed in a helicopter or given the ability to fly, and were either tasked with finding a missing child or were given an aerial tour of the virtual city. After the experience, an experimenter would purposely “drop” a few pens on the ground. This study found that those that were given virtual super powers far more often helped the experimenter pick up the spilled pens, thus leading to the authors’ conclusion that certain virtual reality experiences can promote pro-social behavior in the physical world [43].

Finally, VR can also be a valuable tool in emotional therapy. In 2002, a survivor of the 9/11 attacks on the World Trade Center who suffered from PTSD (Post-Traumatic Stress Disorder) was treated using VR. She had little success with prior forms of exposure therapy, all meant to bring up emotions and images that she had been
suppressing and avoiding. Using VR to simulate being in the middle of the attacks once more, for an hour at a time over six sessions, the participant was clinically measured and “indicated a large (83%) reduction in depression, and large (90%) reduction in PTSD symptoms after completing VR exposure therapy” [17]. Another VR exposure therapy method was used in a 2013 study that aimed to treat social anxiety disorder. A diverse population of participants who identified public speaking as a primary source of anxiety were recruited and randomly assigned to take part in various exposure experiences. These experiences included speaking to a virtual conference room or classroom full of virtual people, as well as recorded in-person group sessions with other participants. Results showed that those who underwent the virtual exposure had just as much benefit as those who underwent in-person exposure therapy [10].
As virtual reality has proven it can be utilized for different forms of therapy, we aim to utilize it in the form of emotional therapy (specifically art therapy). We believe VR can have just as much if not more utility in this field as it has in others. We have developed such an application to test this utility, and have implemented two versions to additionally gauge the link between user interface naturality and user experience and empowerment.

During the experience, players make color choices, either via a button-based control panel or by painting a “planetoid” in front of them, that change the environment. The three environments map to two colors each: an underwater environment is mapped to both blue (water) and white (snow/ice), an open field environment is mapped to both green (grass, leaves, etc.) and yellow (sunflowers, sunshine), and finally a volcanic environment is mapped to both red (lava) and black (ash, rock). All three environments were chosen as calm, quiet spaces that seem interesting to explore. Although six environments is preferable and will be discussed further, three environments were implemented in the interest of time. The “primary color” of the interface determines the environment, being a selection on the button interface in the control version, and being the most common color on the planetoid in the experimental version. Each environment contains an amount of “detail objects” scattered about: underwater is filled with coral, the field is accented with trees, and the volcanic scene is scattered with boulders and statues. These objects change color based on the secondary color of the interface, again chosen either by color on the button interface or this time, by second most common color on the planetoid. The number of
these objects can also be controlled via a button interface in both versions. The three environments have small animated details. These detail objects are intended to give the player further influence over the environment, such as the overall color around them and the “noisiness” of these objects. Underwater, players can find air vents blowing bubbles to the surface, in the field the trees and flowers blow in the wind, and in the volcanic scene the lava is given the appearance of slow, bubbly churning. These and other graphics technologies were implemented to provide further graphical fidelity with the aim of heightened immersion. In this section, we discuss the implementation of these environments and their technologies.

4.1 User Interface

Developing an interface in virtual reality, of course, comes with a number of differences when compared to interfaces on two-dimensional displays; people naturally interact with things in the third dimension differently. Interfaces must account for distance and size in unique ways. For example, Google has presented (at their 2017 Google I/O conference) how even though two-dimensional displays are of course possible in virtual reality, distance and size of canvases, icons, and buttons must be accounted for, and they normalize this by providing their own unit of measurement for development on their own platforms (Figure 4.1) [21].

For this application, we rely mostly on three-dimensional interactive objects rather than two-dimensional displays due to the heightened naturality of interacting with 3-D objects. All actions are done either through interacting with some button in the environment or by pressing physical buttons on the controllers. In-world buttons include the menu system before the game, the detail amount selector to the left or right of the player (which allows the player to change the number of objects in the
Figure 4.1: Google developed their own measurement system for 2-D UI in 3D, focusing on how to change the size of something depending on distance to make the UI take up the same amount of space in the user’s field of view. [21]

environment), a “done” button that allows the player to finish painting and teleport around to explore the environment, and finally a confirmation “yes/no” set of buttons to allow the user to quit the application.

4.2 Planet Painting

The second version of this application allows the player to “paint” the planet they are on, by painting a small planetoid representation in front of them. As opposed to the button-based interface, this interface is intended to give the player a feeling of connection to the space around them. We want the player to feel like the creator of their own planet, giving them a better sense of empowerment and control over their surroundings.

When playing the second version, the player has a brush in one hand and a paint palette in the other (Figure 4.3). As is handled by the ControllerInput, they may
Figure 4.2: The control panel in version 1, allowing players to choose colors to control the environment.

Figure 4.3: In the second version, players can paint a planetoid using a brush and paint palette.
change the size and shape of the brush as they choose, switching between a squared
brush or a more rounded brush, and choosing between six different sizes. Tilting
the joystick on the brush controller left or right changes the shape, and tilting it
up or down increases and decreases the size. To choose a color, the player touches
their brush tip to their desired color on the color palette in their other hand. The
ChooseColor script handles this action, and also changes the color of the brush tip to
correspond with this so the user always knows what color in which they are painting.

To achieve the feature of “planet painting” we explored a couple different tech-
niques. Often times in game development, “painting” effects are achieved through
spawning decals on surfaces, similar to bullet decals in shooter games. This can be
done either by spawning a transparent plane with the desired decal on the point of
the surface, or by wrapping the decal texture onto the object’s texture to match its
curvature. However, for this application we want to track in real time the amounts
of certain colors on the sphere as efficiently as possible, so as to minimize frame rate
dips (which may lead to motion sickness or broken immersion). At every instance of
collision between the player’s paint brush and the planetoid, we must track where on
the model the collision happened, convert this location into texture coordinates, and
use those coordinates to alter the texture appropriately. Furthermore, we must keep
track of the change this action has on the color amounts that already exist on the
texture, depending on brush size and shape, as these color amounts link directly to
changes in the environment. Because of these caveats, our implementation changes
the colors pixels themselves so they can be updated and tracked at the same time.
Future iterations of this work would benefit from a move from this pixel-painting
method to decal plastering, then using a time-efficient method to update only the
pixels that are plastered over. Leaving that for later discussion, painting pixels is the
method used here.
This is the method we used; pixel updating in real time, handled via our TexturePainter script. First, it begins with initializing the appropriate parameters, including size of the texture and some record keeping structures to assist with keeping track of how much of each color exists on the texture at a time. The script listens for any collision with the brush, and once a collision is detected it carries out the necessary tasks.

The first on this list of tasks is to determine where on the texture the collision happened. We achieve this through built-in calls and determine pixel position with respect to the texture by using our uv2PixelCoords function. This function converts the input UV coordinate into basic x- and y- coordinates, as if on a two dimensional plane. Once converted, depending on the aforementioned brush mode (fill or touch), the texture is either filled with the aforementioned brush color using Fill, or passed to the Stroke function.

Fill works by utilizing an array to represent each pixel in the texture. We assign every value in the array to the color of the brush, while also updating a dictionary structure “freq,” which is used to keep track of the state of the texture throughout the script outside of the Fill and Stroke functions. Fill clears this structure and inserts a single key-value pair, where the key is the color and the value is the number of total pixels in the texture. Finally, we actually set the pixels of the texture to the colors in our pixels array, then apply them all at once using Unity’s Texture2D.Apply.

The Stroke function is understandably more complex than Fill. We use the variable “brushSize” (set and updated through the ControllerInput script) to set a radius in which to check pixels, as to avoid having to check the entire texture. We consider only pixels that exist within a square at the collision point and of a height and width equal to the radius squared. While accounting for and wrapping around the horizontal edges, we then check the brush shape. If the brush is a square brush,
we set all pixels in the considered area equal to the current brush color. If the brush is round, we first check every pixel to determine whether or not it lies within a circle of the same radius. If so, we set that pixel to the brush color. In both cases, we update the freq structure accordingly by subtracting one from the pixel’s old color’s value and adding one to the pixel’s new color’s value. Finally, after looping through the necessary pixels and setting their colors, we use Unity’s `Texture2D.Apply` to set them all at once (Figure 4.4).

After the appropriate pixels are updated on the texture, we use a function `printColors` to update our script’s knowledge of what are the first and second most dominant colors on the texture/sphere. Using the freq structure, we loop through every entry and keep track of the two keys that have the highest values - these keys will be the first and second most dominant colors, as they have the first and second most amount of pixels of that color. We then set these two colors (as strings, for example “Red”, “Blue”, etc.) to two public variables (1. `domCol` and 2. `subCol`) that are read throughout the rest of the program to update the environments and objects within.
Figure 4.5: During planet painting, changes to the world are hinted at via “hint objects” that animate out of and back into the planetoid.

4.3 Hint Spawner

In order to test and provide visual feedback from the primary and secondary color variables, we spawn objects from the sphere/planetoid in order to convey, or “hint,” what the world may end up looking like. This is in the hopes that whenever there is a change in environment, the player is made aware of it without having to look up and around from painting the sphere. We have six available colors on the palette: black, blue, green, yellow, red, and white. For each of these, a unique object was created to represent their potential environments. They are a moon (night sky), fish (ocean), tree (forest), flower (field), volcano (lava environment), and a snowflake (snowy environment), respectively. Each object also has specific details separated in the back end to allow the secondary color to be shone through(Figure 4.5). For example, if the sphere is painted mostly red with blue as its secondary (second most dominant) color, the object spawned will be a volcano with blue lava. If the sphere is mostly blue with green as its secondary color, the object will be a fish with green scales. Each object also has its own animation, by which it will grow/move out of the sphere and shrink/move back into it and out of sight. These objects and their
animations are spawned whenever there is a change to the primary or secondary colors.

All of this is handled via the `hintSpawner` script. At the start of the script we spawn and animate the appropriate hint objects by reading the color values from `TexturePainter`. The hint object spawning portion is unsurprisingly the much simpler part of the `Update` function, which is called every frame. This simply determines which object maps to the appropriate color using a few different structures, then spawns and animates said object, making sure to delete the old one to prevent bogging things down.

### 4.4 Virtual Environments

We now come to what could be considered the heart of the functionality of our application, which is handling the changing of virtual environments and their details. In the interest of time, only three of the six possible environments were modeled and built out for this application, but the colors do map sensibly: both red and black map to a volcanic environment, yellow and green both map to an open flowery field, and white and blue both map to an underwater scene (Figure 4.6).

#### 4.4.1 Environment Overview

The volcanic environment surrounds the user with mountains and of course, volcanoes flowing with lava. Large boulders are scattered throughout, all cracked with a color that gives off the appearance that these were made from the same lava that flows along the edges of the scene. Statues are also placed, using the same look as the boulders to imply that they were carved from the boulders. The field environ-
Figure 4.6: Each environment maps to two possible dominant colors (from left to right: Black and Red to Volcanoes, White and Green to Underwater, Yellow and Green to Flowery Field).
ment places the user in an open and flowery field, with rolling hills and trees, both large and small. Flowers blow in the virtual wind and leaves fall from the trees. The underwater environment places the user on an ocean floor. Patches of coral are scattered around the environment, as well as small holes that emit air bubbles. Crashed spacecraft pieces are also placed around the environment, implying a sort of sunken ship story, but colored to look as if they have been there for a long time and have rusted over. The larger objects (statues, large trees, and sunken ships) are placed not only to make the environments more interesting, but also to provide key landmarks so that when exploring the users have anchor points of reference to determine where they are, in addition to the terrain itself.

4.4.2 Order of Operations

Back in the hintSpawner script, these scenes are swapped and animated, linking them to either the user’s control panel or the planetoid the user is painting, again depending on which version they are testing. Similarly to the actual spawning of the hint objects, we check if the primary and secondary colors have changed since the last frame. If the primary has changed and the new color’s environment is not the same as the old color’s (for example, between black and red the environment should not change), we carry out the necessary changes. These changes include changing the ambient environment sounds and handling animations both out of and into the scene. This also switches certain particle effects on and off, which are the leaves from the trees, smoke from volcanoes, and bubbles from underwater vents. In order, the script handles animating the old environment out of the scene, stopping ambient audio tracks, disabling scene-intrusive particle effects, animating the new environment into the scene, and playing the new ambient audio. Fog is handled in its own function, changing density and color appropriately.
4.4.3 Detail Objects

Scattered throughout the three environments are objects that change their color based on what the second most dominant color is at any given time(Figure 4.7). This is to provide more control and empowerment to the player, giving them the feeling that they are in a way the deity of their own world.

For the underwater scene these objects are the coral beds, for the volcanoes this is the lava and the cracks in the rocks and statues, and in the field this is the leaves on the trees. These are the things most often being effected by the user’s painting, and therefore are the key objects that we want to let the user feel they have control over. Both the color and amount of these objects change given the user’s input, as in addition to the planetoid painting they also have a selector to their right where they can choose to have a low, medium, or high volume of things in the environment.

The color of these objects changes with the secondary color, but as we will discuss in the following section, not all objects are the same color. They are instead “analogous” to the secondary color on a given color wheel, and therefore look varied enough to be natural, but uniform enough to match each other. We explored making the color variance match other schemes in color theory such as complementary or tetradic [32], but they varied the colors to the point where the objects did not seem to follow a specific identifiable color, so we settled on the analogous color scheme with some tweaking, seen in Figure 4.8.
Figure 4.7: Accent objects throughout the three environments include coral beds, cracked rocks, and trees. These change color based on the secondary color determined by the player.
Figure 4.8: Detail level can be adjusted by the player, providing sparse to dense patches of objects.
4.4.4 Terrain

Part of creating a realistic environment for the player to experience is the variance in the general terrain setting such as the ocean floor or the hills of an outdoor scene. We tackle this problem by using the built in Unity terrain editing tool.

Unity provides a useful terrain editor tool to create planes and add hills, jagged mountains, and other features that may turn a flat plane into something more realistic. This editor is fairly straightforward on the development end, providing different brushes and intensities by which to either add to or subtract from the plane. Also useful in this terrain editor is the option to paint “grass” to the terrain. This takes in any two-dimensional image or 3 dimensional object and with the same brushes as the terrain manipulator, allows developers to brush billboards of this image or instances of this single model across the ground. This was especially useful in the flowery field environment. We began attempting to place flowers throughout the field by painting the models on in a separate modeling software (Blender), though of course this lead to massive rendering costs that made the application all but unplayable. Using Unity’s grass editor, we fed an image of a flower to the grass generator and set the necessary scale. Unity also applies a sway in grass (in our case, flowers) to simulate wind.

4.4.5 Teleportation

Where this becomes more complex is with the addition of SteamVR’s player teleportation functionality. We wanted to allow the player to explore the environment they created, instead of simply standing and staring at it. We believe exploration is a key aspect of both immersion and empowerment, letting the player do what they want to. Movement in virtual reality often favors teleportation over the classic more iterative movement found in other virtual experiences mainly due to its less-
ened probability to cause motion sickness. With this in mind, teleportation is its own implementation onto the player object in SteamVR, and comes with its own requirements.

For a player to teleport, a player controller and teleport area must both be active. With this in mind, providing the system with an accurate terrain plane for teleportation required modeling software. Any object mesh can be fed into the teleport system as a valid mesh to teleport onto. Feeding this system the exact mesh of our terrain is not ideal, however. This is because while we do want the player to be able to traverse the terrain, we want some areas to be off-limits so they cannot walk to the edge of the world or stand where they are not supposed to (ex. in a pool of lava). Other invalid teleport spots (inside of rocks, trees, etc.) are avoided by adding collision meshes to those objects that are not fed into the teleport system. As far as the terrain mesh however, we must alter the mesh we feed the system. To do this we export the mesh into Blender, then remove parts of the mesh that we do not want the player to be able to teleport onto. Once this is done, we position the new mesh in Unity to line up with the visible terrain object. This “teleport plane” is then only enabled when we want to allow the player to teleport, providing a script-side switch to allow us to make sure players cannot accidentally teleport themselves while they are choosing the colors of the world.

4.5 Shader Graphs

A final factor in immersion is graphical fidelity. While this may or may not mean graphical realism (discussed in chapter 6), a dynamic environment is more likely to hold a person’s interest for a longer amount of time. In typical graphics programming, these effects are often accomplished through shaders that can change
Figure 4.9: All shaders affected by the secondary world color put said color through a randomization step, in which 4 analogous offsets are generated. One of these 5 possible colors are then chosen by a random function seeded by the object’s world position and rotation. The default color node set here is Green.
the color, movement, and other behavior of virtual objects. While Unity does support shader programming through HLSL, Unity 2018 added a shader graph system through which changes can be created and viewed in real time without the need to compile and run to observe every iteration. This saved considerable time during development, and provided a balance between depth of control and not having to reinvent any wheels.

One of the most prominent shader graphs we developed was a simple but effective analogous color scheme shader, by which an object would appear with one of five different colors, depending on that object’s location. This shader (or unique variant of it) was applied to all detail objects to match them with the secondary color, while maintaining their individuality from the other objects. Different color schemes can be identified as their colors’ relative locations to one another on a color wheel. The analogous color scheme is often defined as colors that are “adjacent” to one another [32], meaning within some small degree offset. For this specific set of shaders, that offset is set to twenty degrees in each direction. We repeat that offset to give us five colors: the input base color, two colors twenty degrees in both directions, and two colors forty degrees in both directions (Figure 4.9). While this offset may sound dramatic, it provides just enough variance to produce individuality while still allowing one to mentally tie all colors to a single hue (Figure 4.8). As a disclaimer, this process then does not produce variance when considering black or white, as they are not technically “colors” in the traditional sense, but rather extreme shades.

One unique shader that uses this adjacent color scheme is the treetop shader. In addition to color, the graph also effects vertex position, oscillating them back and forth in a way that simulates treetops shaking in the wind. Other shaders of interest are the lava and water caustic shaders. These are examples of utilization of Shader Graph’s “Voronoi” node, based off of the mathematical concept of the “Voronoi Diagram” [18]. A Voronoi Diagram is a collection of regions on a plane that
Figure 4.10: Unity’s voronoi node, crucial in creating effects like the water caustics, flowing lava, and porous coral. Input ports include 2-D UV value, angle offset, and cell density.

are defined by a point’s relation to control points on the plane. The simplest and most common Voronoi plane is one defined by Euclidean distance, which is also the one used in Unity’s Vornoi node. In such a case, a region is defined by the set of all points whose distance to one control point is less than or equal to the distance to another control point. This can be represented in the mathematical notation:

$$R_k = \{x \in X | d(x, P_k) \leq d(x, P_j) \forall j \neq k\}$$

Wherein first, let $R_k$ be the Voronoi region. This region is then defined as the set of all points within $X$ whose distance to point $P_k$ is less than or equal to their distance to all other points $P_j$ where $j$ is any index other than $k$.

The image this node creates, seen in Figure 4.10, provides a base for these and other implemented shaders. For the water caustics, the edges of the voronoi cells were emphasized and colored a bright HDR blue, and time was applied to the nodes.
Figure 4.11: Combining voronoi, normal mapping, and color offsets produces varied porous coral. Other combinations create flowing lava, cracked boulders, and treetops blowing in the wind.

to produce motion. The lava effect was achieved by lerping between the voronoi in motion and gradient noise, using another noise node (but in motion) as the lerping value, causing the brightness in some spots to follow the voronoi while the top layer followed the moving noise. The coral shader utilized both the voronoi node and the previously mentioned color variation shader to give a porous look to the coral in the underwater environment. This was thanks however not just to voronoi, but also to the use of normal mapping within the shader graph.

Normal mapping is a common concept in computer graphics, but to quickly revisit, normal mapping is used to alter the “perceived surface” of an object to help give it more detail. This leads to light bouncing off of the surfaces in a more dynamic and detailed fashion [15]. With this concept in mind, it is lucky for us that Shader Graph actually supports custom normal mapping, and the porous coral effect was achieved (Figure 4.11). Another shader that utilized normal mapping was the rock shader for the boulders in the volcano environment. To give them a cracked look, it is not enough to strike the models with color lines - the same nodes that produced the lines (again, using voronoi) was used to produce the normal maps. Other shaders that utilized normal mapping are the ground surfaces of all three environments (sandy,
rocky, grassy) and the crashed ship parts in the underwater environment (rusted surface).

4.6 Overview

Together all these technologies create a virtual reality experience in which users can directly influence their environment. They can make color decisions that determine the environment itself, switching between underwater, meadowy, and volcanic environments. Furthermore, players can decide on the amount of object noise they prefer in this environment, along with the overall color scheme of these objects. With these features implemented, this application provides a basis for an experience whose purpose is to empower the player and provide a calm, quiet, and interesting environment to escape to.
For this project, we developed two versions of a virtual reality experience, aimed at providing a therapeutic and empowering space to reduce negative emotion such as depression and anxiety. The two versions were distinguished as such to also test our hypothesis that a more natural user interface provides a better sense of control to the user, further connecting them to their surroundings and empowering them. We conducted limited user testing to determine the viability of VR as an emotional therapeutic and to gauge the importance of UI naturality in such an experience. To understand this and the user experience as a whole we designed a user test that included a pre-experience survey, testing of one version of the application, post-experience survey, and later extended interviews.

5.1 Logging

Due to the current public health crisis, testing for this application became its own final challenge during implementation. While ideally testing would normally take place in-person and in a laboratory, this did not prove to be viable while also observing proper safety protocol and minimizing risk to us and more importantly, the participants. With that being said, our workaround to this is a gamestate logging system. While sending out a packaged .exe to participants is easy enough, we wanted to be sure to capture as many otherwise unnoticeable yet interesting events that may happen, and that the participants may not end up recalling and commenting on during the post-experience survey. This idea spawned from brief beta testing, where
the participant seemed to enjoy spending a lot of time teleporting to the tops of the
hills in the field environment.

The logging system does two important things: it logs raw data and captures
screenshots of the player’s view. Both actions are carried out in the same script.
Unity luckily provides a screen capture function, which we call every three seconds
and save into the appropriate folder. The raw data that gets captured is stored into a
.csv file, which is also saved into the same folder. The data captured and logged here
are the current time, frames per second, dominant color, secondary color, and detail
level. The raw data is meant mostly to monitor the performance of the application,
while screenshots are meant to capture more of those, as mentioned earlier, otherwise
unobserved events that may happen during remote testing.

5.2 Procedure

The testing procedure began with signing an informed consent form to partic-
ipate, informing the participants of what the potential benefits and risks were, as
well as information about what data was to be collected. This encompassed the
aforementioned logged data, and how it would be stored.

Next, participants were asked to complete a short Pre-Experience survey. The
purpose of this was to gather general demographic data about the participants. The
full versions of this and the other surveys can be found at the end of this paper,
though the two main questions were about the individual’s age and their prior expe-
rience with VR. Though we targetted mainly college-age students while looking for
participants, we were still interested in age to discern any potential links between age,
prior experience with this new technology, and their later reactions to the application.
Following the Pre-Experience survey was the testing of the application itself. Participants were evenly assigned to the two different versions of the application, and began the experience in a main menu, wherein the player can choose to read the instructions, play, or quit the application. Instructions gave players controller information and instructions on how to operate the planet painting mechanic, if the version they were playing was indeed the planet painting version.

Participants were not given any strict goal to follow, only to experiment with what they could do and what they could create. No time limit was given, as the application’s purpose is to provide a calming and de-stressing environment for the player to explore and create in. The lack of a central goal lead to an interesting outcome, discussed in chapter 6.

Once participants were satisfied with the experience, they were given a button to quit the game. Finally, they completed a post-experience survey (also found at the end of this paper). The survey asks the user about their experience both with the user interface, with their ability to control the environment, and with their overall satisfaction and emotional response to the experience. After an amount of time, follow-up interviews were conducted with participants to gain a more comprehensive understanding of their experience.
Chapter 6

RESULTS

While our sample size was small, extended feedback brought out key findings during testing. Our final number of participants for this project resulted in six people. While we do not claim the following results to be statistically significant, though we do believe lessons can still be learned. The application has shown to be a strong basis for an empowering experience, with potential features adding to its utility. We also believe the naturality of the UI to correlate positively with user experience, depending on the naturality of the task being carried out by the interface in the first place. More natural actions seem to benefit from a more natural interface, while less natural options tend to provide a better experience when paired with traditional button interfaces.

6.1 Survey Response

Prior to extended interviews, the post-experience survey results were evaluated to identify any significant trends in the group along with any unexpected anomalies. As seen in Table 6.1 and Table 6.2, participants felt satisfied and immersed in the environments they created. After reviewing the logged screenshots as well, some even took their time to pause and take in the environment, relaxing in the flowery meadow especially. However, players also felt that while content in their color choices(Table 6.3), only half were satisfied with the variety of color available to them (Table 6.4). Some suggested the ability to combine colors to create new shades and hues. Another color-related request that came up was while each environment
Table 6.1: Results from a survey question: “How would you rate your own immersion?” with 1 being not immersed at all and 5 being very immersed.

Table 6.2: Results from a survey question: “Please rate your satisfaction with your influence on the environment” with 1 being not satisfied and 5 being very satisfied.
Table 6.3: Results from a survey question: “Are you happy with the (color) choices you made during the experience?”

Table 6.4: Results from a survey question: “Did you feel you had enough color options?”
Table 6.5: Results from a survey question: “How did the experience make you feel emotionally?”

had two “dominant colors” mapped to them, they felt unique environments for each individual color would have been more interesting. In Table 6.5 we can see that emotionally, players felt immersed, calm, and confident. However, some also felt anxious, which became a topic of discussion during the extended interview sessions. Finally, a majority of participants felt somewhat to fully immersed in the experience as a whole.

6.2 Interviews

Extended interviews were later conducted once all results had been collected. The first topic of discussion was about their overall reaction to the experience. With no strict goal in mind, some were confused at the beginning of the experience, unsure about what they were intended to do. This confusion initially overtook any calm or empowered emotions, though once players were able to discern the effect they had on the environment, the experience became both fun and calming for everyone. One participant specifically noted the desire to revisit the grassy meadow, as it had a calming effect on them.
6.2.1 Anxiety

The following discussion topic was anxiety; as about half the participants reported anxious feelings in the post-experience survey despite the goal of the application being to calm the person playing. Some felt anxious feelings may have arisen from inexperience with virtual reality. Others confirmed this, stating that they “weren’t used to being suddenly surrounded by virtual objects... it was unnerving in a sense.” This same individual noted mild thalassophobia (fear of being underwater) which made the underwater environment extremely anxiety-inducing given its relative darkness and realism. Another participant noted a similar fear, but of the volcano environment: “There were statues all around me, everything was red, and I was like, oh no is something about to happen?” After observing this, further research was conducted and it was found that in other studies, VR is sometimes used to purposely induce anxiety to study its effects on task performance [42][28]. These studies include one conducted last year by this project’s own Dr. Zoë Wood [33].

6.2.2 Graphical Realism

Furthermore, participants discussed whether the realism of graphics tended to have a positive or negative effect on their experience. This was met with mixed response, as some stated the more real the graphics were the more immersed in an experience they would be. One response was, “I typically gravitate towards more realistic VR games, like Half-Life: Alyx. They feel more real to me and I’m much more immersed.” Others (particularly those who reported anxiety during the experience) stated, “I’m the complete opposite. The cartoonish look of the graphics in your game actually helped a lot, they felt softer and less scary.”
6.2.3 Additional Features

Next, participants were asked if there were any features they think could have made the experience more enjoyable, immersive, and fun. The main feature request that came up unanimously was the ability to paint other things in the environment with the paint brush. In the logged screenshots some participants can actually be seen attempting to brush the grass and flowers. Another requested feature was further interaction abilities with the environment; “I wish I had more things to control, or maybe like if my movement could effect the environment.” Finally, one participant noted the desire to see more environments, as they wished they had more to spend time in: “It was really really fun, I actually wish I could go back to it now that I think about it.. I just wish there were more environments, that would be even more fun to mess around in.”

6.2.4 User Interface

User interface was the next topic of discussion. Being one of the primary goals of this project, we wanted to know if UI naturality mattered to them and to what extents. Some responded that they felt the button UI was favorable when it came to choosing the overall details of the world, though during exploration something like the paint brush was favorable: “I actually tried both versions, I liked the button one better but if I was able to paint the ground and the trees, then I think the brush would be important.” In this, they concluded that a less natural UI was preferable when making directly mapped decisions about their environment, but more natural UI is preferred when it comes tomiscellaneously interacting with the world. Others felt more empowered with planet painting than they believe they would have been using.
the control panel—“I felt like my actions were more connected to the environment than if I had used simple buttons. I felt like a god!”

6.2.5 VR Adoption

As the adoption of VR technology often drives its development, participants were next asked if they could envision VR as a therapeutic medium, and if so what that experience might look like to them. After a pause, participants said, “We’re not sure, it’s such a new field that I can’t really imagine what that would look like. I know it can definitely be something like that, but maybe it would look like Minecraft or something. Something where you can create and explore completely freely with not having to worry about things like money.” Most participants agreed that such an application would give someone a feeling similar to that of playing a creative video game, where players can create without limits. Having experienced our application, they agree that control over the environment tends to be a calming experience, and the more control one has the more empowered they feel, leading to more calming feelings. Another potential for VR emotional therapy that was discussed is the “field trip” variety of VR. “It can serve as an escape to someone who lives in a city, or is unable otherwise to travel somewhere. They can just sit in the virtual environment and calm down, like they were really there.”

Finally, as a closing discussion we asked participants what they believed the biggest barriers to VR adoption was. They agreed that the most prominent issue with VR is the cost of entry: only up until recently, consumers would need a powerful gaming computer in addition to the VR hardware, adding a hefty price tag to the sizable cost of a VR headset alone. One participant noted, “this (price) seems even more unnecessary when you consider they probably already have a PC or even a Mac, which they have no chance of upgrading and connecting a headset like you would to a
PC." They went on to discuss that at the moment the desire to do something in VR is the same to do something on any other digital medium like a computer or video game. Because of this, the additional costs are even more detrimental to adoption as some people feel they can get the same entertainment value out of more versatile or cheaper technology. One participant however was hopeful for the future of VR, as companies like Oculus are moving away from PC-based virtual reality and focusing on further developing standalone headsets like the Oculus Quest.
This work has provided a solid basis of an application that has shown through limited user testing that it can be used for an empowering experience, and shows promise given a number of feature requests. Once immersed users enjoyed the experience overall and took interest in their environments. They felt a prominent degree of satisfaction with their control over the environment, with some noting the desire to revisit the experience and attempt further exploration. Improvements can be made however, and with the following taken into consideration an even more immersive and potentially therapeutic experience may be built.

7.1 Limitations

Future iterations of this work have much to learn from this project. It was restricted by a few significant factors, the first being that half way through development, the COVID-19 pandemic began. The early blueprints for this work involved many more participants, as well as professional psychiatric evaluation to better evaluate the effects of the two different user interfaces, as well as the emotional effect overall. Testing participation was also greatly limited due to the inability to test efficiently in person, in favor of ensuring the health and well-being of any and all involved. Early pandemic plans involved limited in-person testing at an on-campus laboratory, though ensuring a safe environment proved to consume much more time than anticipated. We were then limited to seeking out those willing to participate that themselves own a PC-based VR HMD, or otherwise that had the ability to (such as the Oculus Quest
+ Link Cable pairing). While the latter of the two is likely to gain popularity in the coming years (Oculus has recently announced the full shift away from their Rift headsets to their Quest line), the required Link cable is costly and therefore less likely to be in someone’s possession. Overall, when doing remote testing with a virtual reality application, the biggest hindrance to results was the hardware requirement. As this thesis aims to address in its own way, though many consumers now own VR headsets, the technology is still not very widely adopted.

7.2 Implementation Improvements

The first of a list of considerations one should make is the virtual reality plugin they use. It’s likely one will gravitate towards the aforementioned UnityXR system. This will be a wise choice, though we advise in-depth research about the state of the system, as well as its projected direction. While SteamVR proved to be a useful plugin for this project, the deprecation halted progress for a significant amount of time while the workaround was determined. This project is also limited to the older version of Unity that supports SteamVR, and therefore does not benefit from any features or patches added after Unity version 2019.3.5f.

The planet painting feature is also one area that tends to bottleneck performance between certain changes. While the algorithm developed only changes and accesses necessary blocks of data (i.e. no iterating over unnecessary texels or indices of data structures), one improvement that was considered in the latter end of development is parallelization. While only certain pixels on the planet’s texture are accessed and changed, we theorize that utilizing Unity’s ParallelFor Job system[8] would speed this process up significantly. This feature uses Unity’s NativeArray data type to store data in which to run across multiple cores at once. With this in mind, one may
create a `NativeArray` of pixels to be checked during painting, and send every pixel’s data (such as uv coordinate and current color) over a `ParallelFor` Job in order to run the same check across all pixels, which are at the moment being iterated over during each dab of the player’s paintbrush on the planetoid.

On the topic of parallelization, another hitch that may be fixed is the translating of objects through the scene during scene changes. Because each environment has a large number of detail objects scattered throughout, a scene change triggers the detail level system to reset to no detail in order to avoid lag that results from the movement of this large number of objects, animating into and out of the scene. These objects do not cause lag while stationary, as they are rendered using Unity’s instanced rendering. However, if one were to develop a system that performs the translations over the `ParallelFor` Job system instead, this jump to zero detail objects between scenes would not be necessary.

Finally, various minute graphics improvements may be made, particularly to textures. Research on procedural terrain may be beneficial, to further improve the terrain in all three environments. Ground textures will also benefit from terrain techniques to avoid texture tiling. On detail objects, improved uv-wrapping may be achieved through Unity’s shader graph system as well, avoiding the texture stretching seen in some images.

7.3 More Features

We also believe this application would benefit from increased features. Initially, one event of the application would see the player creating a three dimensional object, painting in free three dimensional space. This object would be framed as a larger object in the background environment, such as a towering mountain, giant swimming
sea creature, or other large background object. The intention of this feature was to give the player a feeling that they didn’t just decide the colors of the world, but the shape of it as well. The player would be prompted to create this object in front of them similar to something like Tilt Brush[5], and once they were done creating this object it would be enlarged and placed into the background (and animated, depending on the environment). Such a feature would be a sizable task to implement, but may begin with allowing the player to “paint” in three dimensional space, perhaps by continuously spawning some simple geometry from their brush while a button is held down on the controller.

Another potential feature comes not from our initial concept of the project, but rather from observations made during the testing phase. In the case of the Planet Painting version, players often seemed to attempt to paint flowers, the ground, or other objects with the brush. While this wasn’t part of the original application design, adding in the ability to freely paint other surfaces could potentially yield greater feelings of immersion from the player. Finally, any additional methods of interaction and/or influence over the environment would surely prove beneficial, as in the discussion portion it was discerned that deeper environmental control and interaction will likely lead to increased feelings of immersion and empowerment.
Virtual Reality has fluctuated in popularity since its conception. This is due to many factors such as cost, hardware limitations, software limitations, and potential utility. Our work focuses on the possible utility of this technology, as well as an optimization in user experience.

With depression and anxiety on the rise worldwide, it is important now more than ever to explore variations in treatment and what benefits they may have. Therapy has often been a target for VR development, as its immersive capabilities are unparalleled. This project presented a VR application aimed at providing a new medium for a specific kind of therapy: art therapy. This allows individuals to create and express themselves at their own pace, without the need for potentially uncomfortable interaction with others. Through our developed application, users are placed in a virtual world which they influence through color choice.

This application also studies the difference in user experience, comparing response to naturality of the user interface through which players influence their environment. After testing a small sample group with the two versions of the applications, we conclude that VR does indeed pose positive potential as a medium for art therapy. Participants responded positively to the experience, a majority feeling calm and immersed. While some felt anxiety, we determine this to be both unaccustomed experience with the technology and response to specific environments. User interface naturality showed to have a mixed response, some preferring more straightforward
and traditional button-based methods, while others noted the increased connection to the environment the naturality provided.

With the feedback considered, we believe the naturality of a UI in virtual reality can increase immersion and connection between a user and their environment. The degree of this beneficial naturality however, may correlate to the specific effects the interface has. While further testing may confirm or deny this, we believe more natural actions greatly benefit from more natural interfaces, while more synthetic option-based actions benefit from a more straightforward, traditional interface.

Lessons learned during development combined with feedback of the experience, both positive and negative, provide a solid basis for future work. We make recommendations on this ranging from hardware cognizance, implementation improvements, and features we believe will enhance the user experience even further.
BIBLIOGRAPHY


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APPENDICES

Appendix A

INFORMED CONSENT FORM
INTRODUCTION
This form asks for your agreement to participate in a research project on user experience in a virtual reality environment. Your participation involves taking part in two surveys and allowing the use of your anonymous answers in research and analysis. It is expected that your participation will take approximately 45 minutes to 1 hour, depending on your own preference. The potential risks to you by participating are discomfort, nausea, dizziness, eye strain, and in rare cases, seizures. Others may benefit from your participation. If you are interested in participating, please review the following information.

PURPOSE OF THE STUDY AND PROPOSED BENEFITS
- The purpose of this study is to analyze how users respond and react to having certain levels of control over their virtual environment.
- Potential benefits associated with the study include a better understanding of how much personal influence over the environment matters to the user within it, as well as what effect that has on their emotional state.

YOUR PARTICIPATION
- If you agree to participate, you will be asked to put on a virtual reality headset and explore a virtual environment, interact with it to your own satisfaction (movement can include walking within a small area space, reaching up or bending down), and make decisions.
- Your participation time depends solely on your own preference - the virtual experience can be as short or as long as you like, but may take a minimum of 5 minutes. The pre- and post-experience surveys may take approximately 5-10 minutes to complete.

PROTECTIONS AND POTENTIAL RISKS
- Please be aware that you are not required to participate in this research, refusal to participate will not involve any penalty or loss of benefits to which you are otherwise entitled, and you may discontinue your participation at any time. When filling out either survey, you may omit responses to any questions you choose not to answer.
- The possible risks or discomforts associated with participation in this study include seizures, nausea, dizziness, eye-strain, stress or other mild negative feelings.
- You should not participate if you have had negative experiences associated with virtual reality devices.
- All data will be used in final reporting and stored securely and confidentially. All data will be collected through a Google form and (should you opt for it) and experience session recording/screenshots. No revealing information will be presented in the final project, and should any images of said recording be deemed useful for the final report, you will be contacted before they are used.
RESOURCES AND CONTACT INFORMATION

- This research is being conducted by Dr. Zoë Wood and student Matthew Key. If you have questions regarding this study or would like to be informed of the results when the study is completed, you may contact the following researchers: Dr. Zoë Wood (zwood@calpoly.edu), Matthew Key (mkey@calpoly.edu)

- If you have any concerns about the conduct of the research project or your rights as a research participant, you may contact Dr. Michael Black, Chair of the Cal Poly Institutional Review Board, at (805) 756-2894, mblack@calpoly.edu, or Ms. Trish Brock, Director of research Compliance, at (805) 756-1450 or pbrock@calpoly.edu.

AGREEMENT TO PARTICIPATE

If you agree to voluntarily participate in this research project as described and are at least 18 years of age, please indicate your agreement by submitting this google form.

Note: You may still choose to contact us and opt-out of publication of said recording.
Appendix B

PRE-EXPERIENCE SURVEY
EnVRMent: Pre-Experience Survey

In the following experience, you are an intergalactic explorer and you have just come across a strange planet - it’s barren aside from the ocean that engulfs it, but you’re confronted with the ability to change its very nature! Once the planet is to your liking, you decide to explore the area around you before leaving. Once you’re all done, you may feel free to leave the planet and finish the experience, bidding farewell to your creation, but hopeful you’ll come across another!

Before we take off though, we have some quick questions for you:
* Required

1. Email address *

______________________________

2. What is your name? *

______________________________

3. How old are you? *

______________________________

4. What real-world environment will you be playing in? *

Mark only one oval.

☐ Controlled Laboratory (on campus)

☐ Personal Space (bedroom, home office, living room, etc.)
5. What is your prior experience with Virtual Reality? *

*Mark only one oval.*

- [ ] I have never used a VR headset
- [ ] I have had demo-level experience (at a friend's house, arcade, mall, etc.)
- [ ] I own a VR headset  
  
  Skip to question 6

Section 2

6. Which VR headset do you own?


7. How long would you describe your average usage is?

*Mark only one oval.*

- [ ] Once every few months
- [ ] Once every few weeks
- [ ] Once every few days
- [ ] Frequently

8. What was your primary reason for getting a VR headset in the first place?


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Appendix C

PRE-EXPERIENCE SURVEY QUESTIONS LIST

General Demographic Questions

1. What is your name? (open text response)

2. How old are you? (open text response)

3. What real-world environment will you be playing in? (Controlled Lab or Personal Space)

4. What is your prior experience with Virtual Reality? (Never used, Demo-level experience, or I own a VR headset)

If the fourth question above was answered with "I own a VR headset," the following questions were asked:

1. Which VR headset do you own? (open text response)

2. How long would you describe your average usage is? (once every few months, weeks, days, or frequently)

3. What was your primary reason for getting a VR headset in the first place? (open text response)
Appendix D

POST-EXPERIENCE SURVEY
EnVRMent: Post-Experience Survey

Thank you for participating in this experience. Before you go, we have a few quick questions for you:

* Required

1. Email address *

2. What is your name? *

3. Was the UI intuitive (easy to use & understand)? *

   Mark only one oval.
   
  ☐ Yes
   
  ☐ No

4. Which method did you use to affect the world? *

   Mark only one oval.
   
  ☐ Planet painting   Skip to question 5
   
  ☐ Control panel of colors   Skip to question 10

Planet Painting
5. Were you able to paint the sphere? *

*Mark only one oval.

☐ Yes
☐ No

6. Did you feel you had enough control over the painting mechanics? *

*Mark only one oval.

☐ Yes
☐ No

7. Were you able to switch colors using the paint palette? *

*Mark only one oval.

☐ Yes
☐ No

8. Could you rotate the sphere? *

*Mark only one oval.

☐ Yes
☐ No

9. Were you able to rotate the sphere in the ways you wanted to? *

*Mark only one oval.

☐ Yes
☐ No
Control Panel

10. How intuitive (easy to use) was the control panel? *

*Mark only one oval.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>It was very self-explanatory</td>
</tr>
<tr>
<td></td>
<td>It was confusing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finishing Up

11. Did you feel you had enough color options? *

*Mark only one oval.

- Yes
- No
- Other: ____________________________

12. Were you able to push the "Done" button and explore the environment around you? *

*Mark only one oval.

- Yes
- No
13. Are you happy with the (color) choices you made during the experience? *

Mark only one oval.

☐ Yes
☐ No
☐ Maybe

14. Please rate your satisfaction with your influence on the environment: *

Mark only one oval.

1 2 3 4 5

Very unsatisfied       Very satisfied

15. Were the visuals enjoyable to you? *

Mark only one oval.

☐ Yes
☐ No

16. In your opinion, did all the visuals “fit” each other and the environment as a whole?

* 

Mark only one oval.

☐ Yes
☐ No
17. How would you rate your own immersion? *

Mark only one oval.

<p>| | | | | | |</p>
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<thead>
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<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>not at all</td>
</tr>
</tbody>
</table>

18. How did the experience make you feel physically? *

Check all that apply.

- [ ] Immersed
- [ ] Out of place
- [ ] Nauseus
- [ ] Uneasy
- [ ] Calm

Other: [ ]

19. How did the experience make you feel emotionally? *

Check all that apply.

- [ ] Empowered
- [ ] Immersed
- [ ] Anxious
- [ ] Calm
- [ ] Confident

Other: [ ]
20. The experience was: *

*Check all that apply.*

- [ ] Boring
- [ ] Fun
- [ ] Therapeutic
- [ ] Interesting
- [ ] Engaging
- [Other: ]

21. How would you rate your control over your surroundings? *

*Mark only one oval.*

1 2 3 4 5

I had no control  [ ]  [ ]  [ ]  [ ]  [ ]  I had complete control

22. Were you able to create something you enjoyed exploring? *

*Mark only one oval.*

- [ ] Yes
- [ ] No

23. Please explain below if you felt anything could/should have been added to give you more control over the environment:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
24. Aside from the above, what changes would you make to the experience if you could?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

25. Would you recommend this experience to: (mark all to whom you would recommend) *

* Check all that apply.

☐ A friend
☐ Someone my age
☐ Someone younger
☐ Someone older
Other: _____________________________________________________________

26. Would you like to be notified of the results of this experiment? *

* Mark only one oval.

☐ Yes
☐ No

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Appendix E

POST-EXPERIENCE SURVEY QUESTIONS CATEGORIZATION

E.1 General Questions

• What is your name? (open text response)

• What method did you use to affect the world?
  – Planet Painting
  – Control Panel of buttons

• Please explain below if you felt anything could/should have been added to give you more control over the environment: (open text response)

• Aside from the above, what changes would you make to the experience if you could? (open text response)

• Would you recommend this experience to: (mark all whom you would recommend)
  – A friend
  – Someone my age
  – Someone younger
  – Someone older
  – other

• Would you like to be notified of the results of this experiment?
  – Yes
E.2 Questions about immersion and functionality

- Was the UI intuitive (easy to use and understand)?
  - Yes
  - No

- Were you able to paint the sphere?
  - Yes
  - No

- Did you feel you had enough control over the painting mechanics?
  - Yes
  - No

- Were you able to switch colors using the paint palette?
  - Yes
  - No

- Could you rotate the sphere?
  - Yes
  - No

- Were you able to rotate the sphere in the ways you wanted to?
  - Yes
• How intuitive (easy to use) was the control panel?
  
  – 1 (It was confusing)
  – 2
  – 3
  – 4
  – 5 (It was very self-explanatory)

• Were you able to push the "Done" button and explore the environment around you?
  
  – Yes
  – No

• In your opinion, did all the visuals “fit” each other and the environment as a whole?
  
  – Yes
  – No

• How would you rate your own immersion?
  
  – 1 (not at all)
  – 2
  – 3
  – 4
  – 5 (completely immersed)

• How did the experience make you feel physically? (check all that apply)
- Immersed
- Out of place
- Nauseus
- Uneasy
- Calm
- Other

• The experience was: (check all that apply)

- Boring
- Fun
- Therapeutic
- Interesting
- Engaging
- Other

• How would you rate your control over your surroundings?

  - 1 (I had no control)
  - 2
  - 3
  - 4
  - 5 (I had complete control)

E.3 Questions about emotional response

• Did you feel you had enough color options?
• Are you happy with the (color) choices you made during the experience?
  – Yes
  – No

• Please rate your satisfaction with the environment:
  – 1 (Very unsatisfied)
  – 2
  – 3
  – 4
  – 5 (Very satisfied)

• Were the visuals enjoyable to you?
  – Yes
  – No

• How did the experience make you feel emotionally?
  – Empowered
  – Immersed
  – Anxious
  – Calm
  – Confident
  – Other
• Were you able to create something you enjoyed exploring?
  
  – Yes

  – No