Evaluating stress recovery by exposure to nature in virtual reality

by

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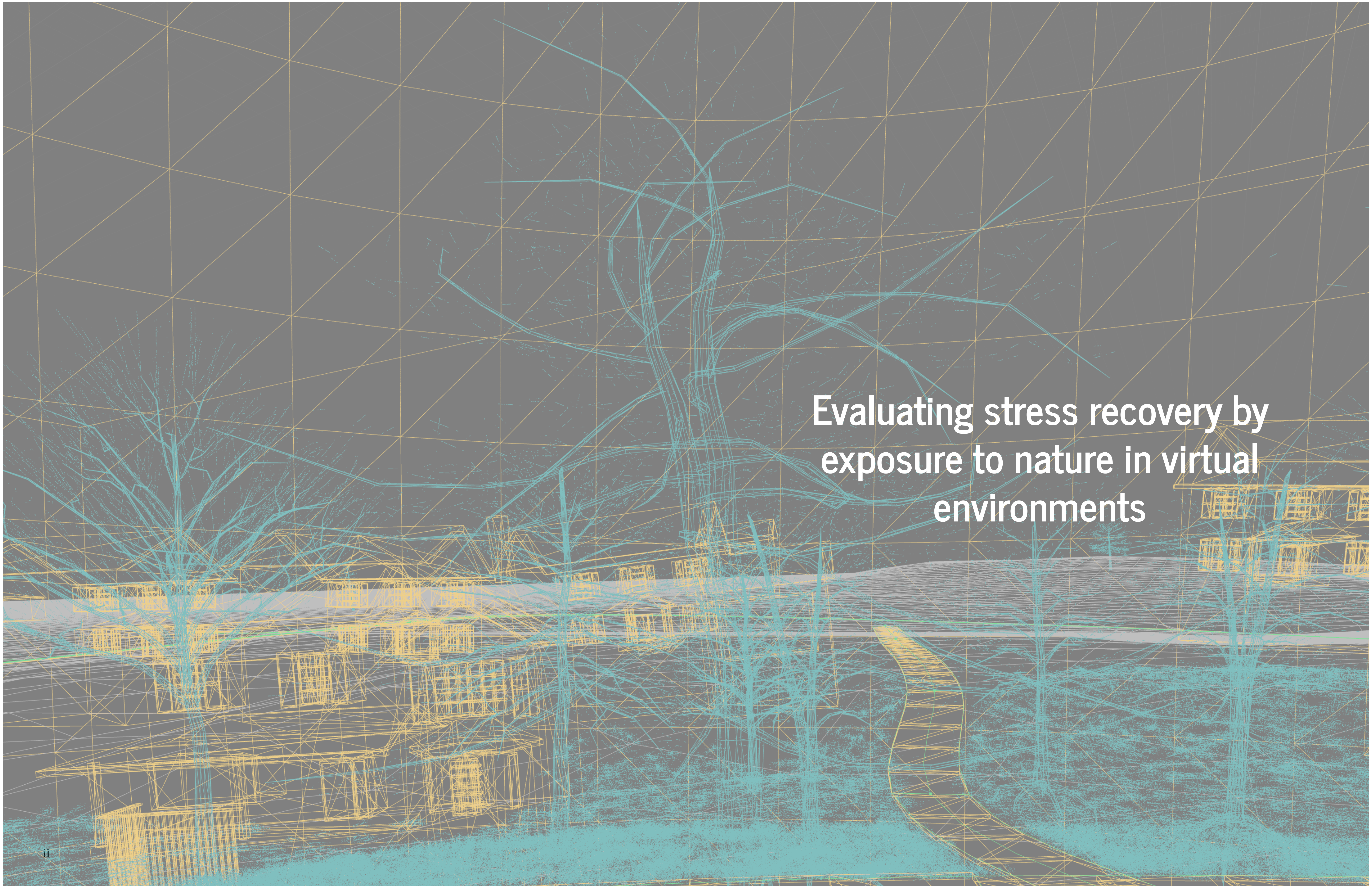

Evaluating stress recovery by exposure to nature in virtual environments

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Acknowledgments

To my **family** for their continuous support throughout this entire process.

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Abstract

The purpose of this research is to identify if virtual reality environments with varying degrees of exposure to nature influence stress recovery at different rates. In 1991, environmental psychologist and architect, Rodger Ulrich, conducted a study on how varying degrees of exposure to nature influences stress recovery by showing participants videos with different levels of nature. His research concluded that participants who viewed the tapes containing scenes with higher degrees of nature recovered from stress quicker than those shown the tapes with higher degrees of human intervention. To expand on this research, it is important to understand how different mediums influence stress recovery. In particular, analyzing how fully immersive virtual reality environments influence the amount of time it takes to recover from a stressor. Virtual reality is particularly beneficial for testing as it enables variable isolation and complete environmental control. A test similar to Ulrich's was conducted in three parts, a baseline, a stressor, and a stress recovery period. Two environments with varying degrees of human intervention were tested. The virtual reality environments were strategically designed along a same path to minimize the addition of extraneous variables. During this test, biometric data was taken in addition to stated stress levels and stated affective response. The study concluded that regardless of the environment type, participants lowered their baseline stress level. This study represents one of the firsts of its type and can serve as a valuable learning mechanism for testing in virtual reality. Results show promise for mitigating stress levels. However, it is recommended that a similar study be replicated in a more refined manor. Lessons learned from this study could be used to inform future studies investigating the effect of VR environments on stress and mental health.

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1. INTRODUCTION

Research Question:

Does the degree of exposure to natural elements have an effect on stress recovery in virtual reality environments? Specifically, is there a correlation between biophysical measures of stress and degree of nature one is exposed to?

Objectives:

1. To review existing literature on the advantages and limitations of virtual reality use.
2. To review existing literature on the biophysiographic impact of nature.
3. Identify three elements with "varying degrees of nature" to be tested in the virtual reality environment.
4. To create a 3D Virtual reality simulation that test the varying degrees of nature and their biophysical impact on test subjects.
5. To conduct a test with three different VR environments.

Introduction

According to the American Psychological Association (APA), Americans are reporting stress to be at an all-time high (APA 2016). Millennials are especially feeling the stress reporting average stress levels (on a 1-10 scale) at a 6.0, much higher than the 4.3 reported by the Baby-boomers (APA 2016). In a world where people are overworked, and constantly behind computer screens, stress levels are especially high in workplaces as well as universities (CNN 2016, Williams 2003). We can begin to understand stress by evaluating several theories coined by environmental psychologists. These theories include Directed Attention Fatigue, the Rest and Recuperation variables, and Attention Restoration Theory (Kaplan 1995, Kaplan et. al 1998, Kaplan 1989). Directed Attention Fatigue is a "prolonged mental effort" which often results in stress and other negative side effects (Kaplan 1995). This forced attention consequently leads to overall reduced productivity and efficiency (Kaplan 1995). This phenomenon often culminates in heightened stress levels, declined health, and declined overall quality of life. Stress is much more than just a mental burden and can have a direct negative effect on health and well-being (Cohen et. al, 2012). However, there has been significant research providing evidence that exposure to nature can reduce stress (e.g. Ulrich 1991, Kaplan et. al 1995, Berman 2008). Several models and variables have been introduced to help understand how to cope with and avoid stress. Along with directed attention fatigue, these theories include Kaplan et. al's Rest and recuperation (R&R) theory which consists of a list of variables significant to stress reduction (Kaplan et. al 1998). Ulrich's Stress Recovery Theory (SRT) shows that nature can reduce arousal and promote stress recovery (Ulrich 1991).

In 1991, a team of psychologists and architects conducted a study analyzing stress recovery in urban and natural environments (Ulrich 1991). Rodger S. Ulrich and team gathered 120 undergraduate students at the University of Delaware to test stress recovery time in six different environments (Ulrich 1991). These environments (which will be discussed in detail in the methodology) were randomly and evenly distributed (Ulrich 1991). During the testing procedure, five types of biophysical data was collected from the participants. The results of the study were consistent with the hypothesis, that stress recovery time in nature were much quicker than those in urban environments (Ulrich 1991).

1.1 Gaps in Current Research

While exposure to nature has been proven to reduce and mitigate stress (Ulrich 1984, 1986, 1991; Kaplan, 1989, Kaplan et. al 1998,), the relationship between the amount of exposure and the amount of stress reduction is unclear. Current research shows it is unclear if simply seeing a tree is more beneficial than being fully immersed in a large cluster of trees in a more natural setting. Many tests of this nature were conducted in reality or virtual settings. To date, little research in environmental psychology has been conducted in fully immersive technology. **The purpose of this research is to expand upon Ulrich's study on stress recovery on a smaller scale to see how stress recovery time is influenced by varying degrees of exposure to nature (Ulrich 1991)**. This will be tested using fully immersive 3D virtual reality environments.

With technologic advancements, virtual reality is becoming increasingly available to researchers, students, and even home users. This technology provides limitless possibilities and can allow individuals to fully immerse themselves in an environment. In addition to full immersion, virtual reality enables complete control over environmental variables making things once difficult to test conceivable. Prior to this technology, trails could not be manipulated in a way that isolates individual variables. The alteration of virtual trails is relatively simple. **The goal of this research is to use 3D virtual environments to control the level of nature exposure and facilitate testing the biophysical stress response to varying degrees of exposure to nature.** If this research concludes virtual reality does influence stress recover, this research could play a valuable role in public health and mitigating stress in the work place. Additional value in architectural fields is endless.

Ulrich's research will serve as an important baseline to this study. This previous study was extensive, examined opposite extreme environmental conditions, see Figure 3.2.1 (Ulrich 1991). Existing research currently lacks evaluation in the amount of nature needed to recover from stress. While many studies have concluded that nature has a greater impact than that of an suburban environment, it is still unclear whether urban green spaces elicit the same response as a wilderness space.

1. LITERATURE REVIEW

Literature Review

2.1 Stress

Jobs, finances, and relationships are some of the top causes of stress in the United States (Ishaque 2015; Williams 2003; Williams et. al 2004). Modern workers are often under high pressure to perform tasks under strict time constraints (Williams et. al 2004; Ishaque 2015). College students in general are very susceptible to stress (Ross et. al 1999). Along with the pressure of succeeding, students feel social, academic, and financial stress (Ross et. al 1999). Dental students in particular ranked overload of work, along with the fear of failing the most common reasons for stress (Ishaque 2015). However, dental students are not the only ones feeling the pressure. On the other hand, work place stress is attributed to "poor communication, low participation, and role ambiguity" (Williams et. al 2004). Though common, stress is detrimental to our well-being (Williams 2003; Cohen et. all 2011; American Institute of Stress 2016). Those under stress often report irritability, reduced interest in life, and poor concentration (Williams 2003). On top of being mentally drained, people experience physical effects of stress as well (Williams 2003). According to the American Institute of Stress, 75% of doctor visits are for "stress related ailments" (American Institute of Stress 2016). Nurses are warned to look for physical symptoms of stress which include; inability to sleep, lethargy, headaches, gastrointestinal problems, and appetite changes (Williams 2003). Exposure to stress enhances your chance of catching the common cold, being overweight, having asthma, and developing unhealthy habits (Cohen et. al 2011; Jiang et. al 2016). Chronic stress can lead

2.1.1 Environmental Psychology

Our environments play a major role in our susceptibility to stress. Environmental psychology, which can be defined as "the transactions between people and places," first gained recognition around 1958 in New York City (Sutton 2009). Though a relatively young topic, significant research has been conducted examining the psychological impact of spatial characteristics (Berman 2008; Cheung 2004; Kaplan 1995; Kaplan et. al 1998; Louv 2011; Ulrich). Several studies in this area have shown nature to be specifically beneficial in stress recovery (Jiang et. al 2016; Kaplan 1995; Ulrich).

In addition to high pressure jobs, readily available technology is decreasing the amount of time people spend in nature (Louv 2011, Nielsen 2016, CNN 2016). Time previously spent outside is now spent behind a screen. In 2016, the Nielsen Total Audience report released the shocking statistic that American adults average just under 11 hours per day of screen time (Nielsen 2016, CNN 2016). As our time spent shifts to the virtual world, we lose quality time spent with the place proven to reduce stress. As a result, our 'vigilance and alertness' is compromised along with our ability to fully develop our senses (Kaplan 1995; Louv 2011).

In 1984, Roger S. Ulrich discovered that hospitalized patients recovered much quicker in rooms that provided a window with a scenic natural view as opposed to those with a view of a brick wall (Ulrich 1984). This is one of the first studies proving that full immersion in nature was not necessary to experience benefits (Ulrich 1986). Several years later, Ulrich analyzed the stress levels of test subjects before and after viewing slides of natural settings (Ulrich 1986). The study resulted in a positive correlation of reduced stress levels following the images of nature (Ulrich 1986). Like imagery, the sound of nature alone can produce a significant positive psychological response (Alvarsson 2010).

2.1.2 Theories

Many theories attempt to explain why nature aids in stress reduction. One popular theory is that nature brings people to the present moment by diverting inward thoughts to the outward world (Freeman et. al; Kaplan 1995). Freeman et. al defined the word presence as "the extent to which the observer feels apart of [an] environment" (Freeman et. al). Stephan Kaplan, recognized nature's ability to grasp presence and created the term ART, Attention Restoration Theory (Berman 2008; Kaplan 1995). The purpose of ART is to distinguish the difference between voluntary and involuntary attention (Berman 2008). Directed attention describes an attention mechanism that requires inhibition and effort often resulting in mental exhaustion (Kaplan 1995). Modern tasks in combination with underdeveloped sensory responses are forcing humans to exert more effort in their daily tasks (Kaplan 1995). Negative impacts of directed attention fatigue include but are not limited to; irritability, impulsivity, boredom, and fragility (Kaplan 1995).

Nature on the other hand, naturally grasps attention without exhausting the mental capacity (Kaplan 1989; Abraham et. al 2009). In their book, "Experience of Nature: A Psychological Experience" Kaplan and Kaplan explain that nature allows the opportunity to distance oneself from their everyday life and experience constant discovery (Kaplan 1989). Unlike the attentional fatigue felt at work, this attention allows the mind to wander freely reducing the negative side effects discussed prior (Kaplan 1989).

Rest and recuperation (R&R) is a Kaplan et. al theory that analyzes five variables that contribute to stress recovery and recovery from directed attention fatigue (Kaplan et. al 1998). While the theory itself doesn't explain why nature reduces stress it helps analyze individual variables found in nature that often promote relaxation and recovery (Kaplan et. al 1998). The variables; quiet fascination, wandering in small spaces, separation from distraction, materiality, and window view, can be contradictory to other studies (Kaplan et. al 1998). For example, quiet fascination explains how quiet places lead to stress recovery (Kaplan et. al 1998). While this may be true, it has been previously mentioned that nature sounds can also elicit positive stress recovery responses (Alvarsson 2010). Additionally, some people may find complete silence to be frightening as people may be afraid of being in complete solitude (Kaplan et. al 1998).

Another, more abstract attempt to theorize the benefits of nature suggested the idea that humans are naturally attracted to images displaying fractal characteristics, which are shown to prove cognitive function (Cheung, Wells 2014). Other possibilities discussed by Cheung and Wells include the idea that "humans' long term natural environments [resulted in physiological and psychological] adaptation to natural as opposed to urban, physical settings" (Cheung, Wells 2004). Another theory similar to Kaplan's is that nature is simply easier to process (Cheung, Wells 2004; Hughes; Wohlwill 1983).

2.1.3 Preferences

Kaplan et. al describe preferences in trail designs and wayfinding. Because this study aims to analyze the experience on trails, it is important to incorporate these variables (Kaplan et. al 1998). Preference is important because it enhances "effectiveness" and helps people feel comfortable in their environments (Kaplan et. al 1998). However, it is also important to note that preference is subjective and varies amongst trail user (Symmonds et. al 2000). For example a study on mountain bikers showed that those with experience preferred rougher terrain than those who had little to no experience (Symmonds et. al 2000). However, Kaplan et. al generalized the following variables (Kaplan et. al 1998). Visual access to areas help improve confidence and reduce possible fear of the unknown (Kaplan et. al 1998). Other variables that decrease fear are signs of human intervention and familiarity (Kaplan et. al 1998). People also generally prefer smooth ground, coherent areas, mystery, a sense of depth, and openings (Kaplan et. al1998). Variables selected for use in this study will be described in more detail in the design section of the methodology be described in more detail in the design section of the methodology.

2.3 Virtual Environments

In a seemingly contradicting method, this study is designed to be conducted in a virtual reality environment. As a “fully immersive” technology, virtual reality provides the opportunity to experience places once seemingly impossible to explore. A study on the effectiveness of architectural research in virtual reality environments states, “Virtual reality allows for highly-detailed observations, accurate behavior measurements, and systematic environmental manipulations under controlled laboratory circumstances” (Kulgia et. al 2015). While we can control variables in the natural world, complete control is nearly impossible. Virtual reality on the other hand provides the opportunity to disengage undesirable variables that may impede test results (Kulgia et. al 2015). This is especially true regarding testing in outdoor environments as we cannot prevent weather and other intrusions. Additionally, some testing grounds may also benefit simply because environmental variables are easier to manipulate. Like video games, virtual environments can elicit emotional responses (Ravaja et. al). Ravaja et. al analyzed the emotional stress response of different video games and found that video games have a great potential to evoke an emotional response (Ravaja et. al) However, one’s level of “presence” plays an impact on how significant this emotional response is.

On the contrary, there are many variables specifically in nature, that cannot currently be replicated in virtual environments (Kulgia et. al 2015; DeKort 2003). This includes weather, wildlife, and other variables. Another study, comparing the differences in virtual reality and reality found that virtual reality made it difficult for people to “[integrate] spatial information to configurational knowledge of a space” (DeKort, 2003). The same study acknowledges the continuous advancement in these technologies and implies that while some virtual reality features currently fall short, updates are soon to catch up to speed (DeKort, 2003). However, since this is a relatively old study, there has there has been much improvement to virtual reality and these features are likely accounted for. Today virtual reality is nearing the point of augmented reality (France-Presse 2017). The newest Oculus Rift provides positional tracking, a 110 degree vision field and a frame rate of 90Hz (Shanklin 2017). This shows major improvements from the Oculus Developer Kit, which was released in 2014 with a frame rate of 72Hz (Rift Info 2016, Road to VR 2014).

3. METHODOLOGY

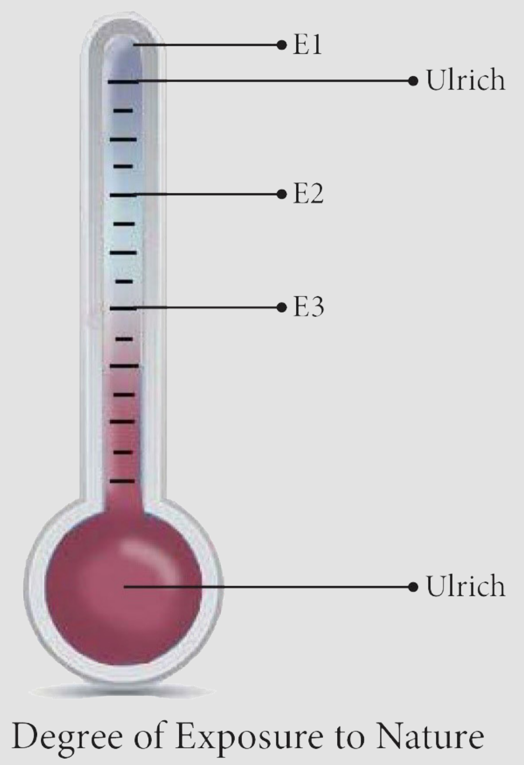


Figure 3.1.1. Degree of Exposure to Nature *Source: Vallo*

METHODOLOGY

3.1 Environment Designs

The 1991 study conducted by Ulrich examined extreme variables pertaining to stress recovery in urban and natural environments (Ulrich 1991). The goal of this study is to evaluate the lesser extremes and investigate if green spaces with a high degree of exposure to nature are more effective in reducing stress than those with a lesser degree of exposure in virtual reality environments. Figure 3.1.1 shows the hypothetical extremes tested in Ulrich's studies versus the environments tested in this study. The five rest and recuperation variables discussed in Kaplan et. al.'s *With People in Mind* played a major role in designing these environments (Kaplan et. al 1995). The variables listed in the book include; quiet fascination, wandering in small spaces, separation from distraction, and materiality (Kaplan et. al 1995). Because virtual reality causes people to become fully immersed in environments, quiet fascination and separation from distraction were relatively easy to apply to the environment. Materiality was also taken into consideration. This included plant palate, ground materiality, and materials in the built environment. The main difference between environments is the degree of human intervention. In Kaplan et. al's research, there is some discretion whether or not human intervention is necessarily a good thing (Kaplan et. al 1995). For example, on wilderness trails human intervention can sometimes be perceived as a threat (ex. Graffiti), but can also serve as a sense of comfort (Kaplan et. al 1998).
Due to limited material access and time constraints, only two of the three environments were actually created and tested. Literature review played a major role in the primary designs of the environment. It was discovered early on that the learning curve for the 3D modeling software, Unreal Engine 4, was much slower than originally expected. This significantly altered the designs which will be discussed further in the environment creation and discussion. With limited knowledge of the program the original designs were altered as needed. The goal was to keep participants in the virtual environments for ten minutes allowing them enough time to recover from stress, as demonstrated by Ulrich (1991).

The environments were designed heavily based on literature review. Much of the variables discussed in the theory and preference portion of the literature review were incorporated into the final environment designs. Environment 1 (figure 3.1.2) is designed with the highest degree of removal from society. There are no houses, and very little indication of human intervention aside from the actual path allowing for a separation from distraction (Kaplan et. al 1998). Environment 2 was actually built first and duplicated. Once duplicated, the sidewalk in

Environment 2 was erased and replaced with a dirt trail. The houses in Environment 2 were then removed. Thus, the trees in both environments are in the exact same places. The manicured grass from Environment 2 was replaced with wilder, more colorful grass in Environment 1. The terrain is also consistent between both environments. By enclosing the environment with gentle sloping hills and a high density of trees, attention is diverted outwardly aiming to reduce attention labor (Kaplan 1995). This coincides with ART (Kaplan 1995). The original design for Environment 1 suggested a much denser forest. However, in order to keep the environments as similar as possible for testing, the trees were placed so houses are visible in the second environment. After taking out the houses from Environment 2, the spaces where the houses were allowed for visual access which when evaluating stress recovery, may actually be better as it is a form of comfort for people that can eliminate fear (Kaplan 1995). Environment 2 simulates a highly naturalized suburban neighborhood. There is a much higher degree of nature in this suburban setting than in normal suburban environments. Additionally there is no vehicular circulation through the environment. There are visual sidewalk intersections in this environment and a much higher degree of human intervention. However, all trees still remain in the same place as Environment 1. Environment 3 is conceptual and if time allowed, would simulate a more industrial / urban trail. This environment was proposed to have the highest degree of human intervention.

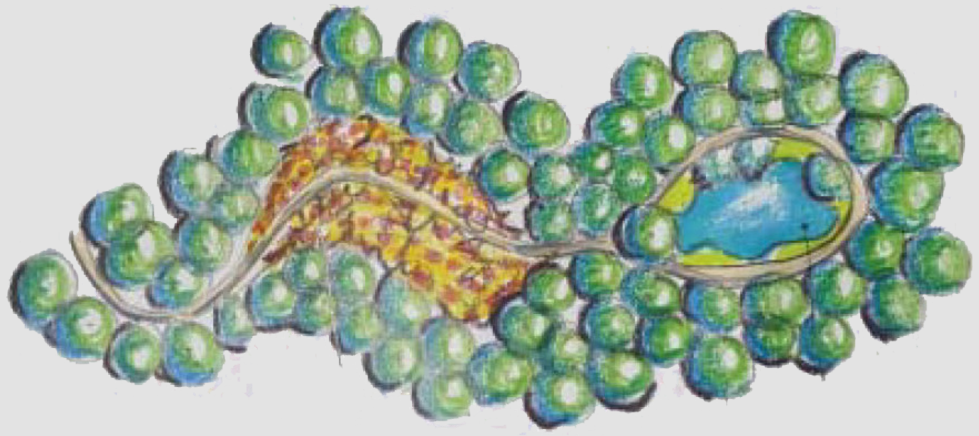


Figure 3.1.2. Original Environment 1 concept. Highest degree of nature, lowest degree of human intervention. *Source: Vallo*

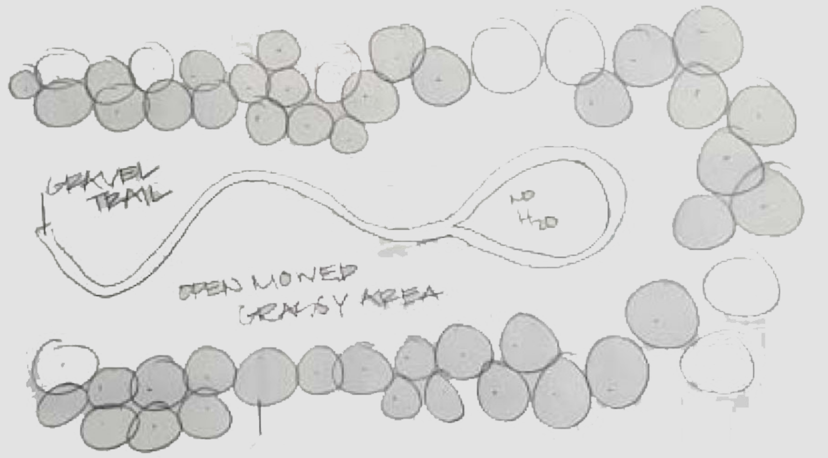


Figure 31..3. Original Environment 2 concept. Moderate degree of human intervention. *Source: Vallo*

Figure 3.2.3. Original Environment 3 concept. Highest degree of human intervention. Little natural. *Source: Vallo*

Test/Variable	Unit/Value	Description and Supporting Literature
Demographics Survey	Basic	Basic
Age	Integer	
Gender	M/F	
Ethnicity	General	
Anxiety Levels	Self-evaluation	Ruskamp, Parker 2016
Empathy	Self-evaluation	
Prior VR experience	Y/N	
Biometric Data		
Galvanic skin response	Siemans	(Empatica)
Blood Volume Pulse	BPM	(Mindmedia)
Temperature	Fahrenheit	(Bio-medical)
Virtual Environment		
Environment Type	E1 or E2	(Vallo)
Additional Surveys		
Percieved Stress levels	Integer	Periodically reported during test (Ulrich 1991)

Table 3.2.1. Variable table *Source: Vallo*

3.2 Variables

The complete list of variables that will be tested can be seen in figure 3.3.1. Demographic data will be used to supplement test findings to see if the variables will play a role in s tress recovery. The biometric data will be taken using the infiniti systems and the E4 Empatica watch. Both systems test the same variables. While the infiniti systems offers a large array of potential variables to test, the most valuable to for this particular test are skin conductance, temperature, and BVP.

3.2.1 Skin Conductance

Psychological testing of SC (skin conductance) or EDA (electrodermal activity) resonates in research on fight or flight responses (Psychlab 2017). In an instance of perceived threat, perspiration occurs (Psychlab 2017). Emotions can also cause a person to perspire (Psychlab 2017, iWorx Systems 2013, Empatica). This response is generally miniscule and not noticeable (Psychlab 2017). However, systems like the infiniti system are able to pick up on this small change (Psychlab 2017, iWorx Systems 2013, Empatica). When one undergoes stress the hippocampus and amygdala are activated producing a change in skin conductance (Empatica). This causes a change in electric occurrences on the skin's surface which can be picked up by the watch (Empatica). This type of testing is common for lie detection (iWorx Systmes 2013). It is also one of the fastest devices to test stress (Healey et. al 1999).

3.2.2 Blood Volume Pulse

The second variable tested by the infiniti systems is BVP (Blood Volume Pulse). BVP works by measuring the rate of blood flow to a non-dominant small figure (Mindmedia, Infiniti Systems). Infrared lights in the BVP sensor measure heart rate by detecting the amount of light reflected back (Thought Technology 2010). This technology is commonly seen in stress assessments as it primarily detects heart rate which slows as emotional state is calmed (Mindmedia). One of the major benefits in using BVP is that it takes non-invasive continuous data (Healey et. al 1999).

3.2.3 Temperature

The third variable tested using the Procomp Infiniti System is temperature. This is tested using a thermistor which is a small linear device that will be attached to the participants non-dominant middle finger. The thermistor takes the rise or fall in temperature and converts it to the "change in electrical current" (bio-medical). Cooler temperatures reveal that the body is undergoing a stress response (bio-medical). Changes in temperature are much less apparent than those seen in BVP and EDA (Bio-medical, Infiniti Systems, Thought Technology 2010).

3.2.4 Other Variables

Additional data were collected using surveys. The pre-test questions on the experimental results was useful in determining habits and trends in connection to their respective results. Thus, it was important to ask about lifestyle as well as anxiety. Questions regarding anxiety include; how much control of life people felt they had, frequency of anxiety, stress, nerves, and other events in the past month. People who experience more anxiety or have a particularly heighted anxiety at the time of the test are probably more likely to report higher perceived stress levels. It was important to see if any of these variables may predict the final outcome. In addition, participants were asked how empathetic they were. People with more empathy may report higher levels of stress following the video portion of the test. Ability to deal with blood and frequency of watching scary movies was also taken in to consideration as a possible predictor of the perceived stress following the video. Other variables that may influence test results were asked including caffeine use, alcohol consumption, and recreational drug use. It was also important to collect basic demographic information during this survey. The full survey is attached in Appendix I.

Figure 3.3.1: Testing location, Day 1. Kansas State University, Weigal Library.

Figure 3.3.2: Testing Location, Day 2. Kansas State University, APD West.

3.3: Participants

Originally, the goal was to recruit participants in advance. However, time limitations complicated recruitment. Unforeseen concerns with the industrial accident video, *It Didn't Have to Happen,* concluded in a delayed IRB acceptance. This mis-stratigized plan and normal processing made the schedule tight preventing formalized recruitment. Therefore a convenience sample was taken rather than conducting a more widely-advertised research study. Because there was little time to recruit, the first set of participants were close friends who were asked to volunteer their time as well as to help recruit other participants. Ten participants were tested on this day. After day one, the location of testing was switched from Kansas State University's Weigal Library, to Kansas State University's Architecture studio swing space. It would have been preferable to have a dedicated space but this was not possible due to the building migration and the urgent need to recruit individuals- making outside arrangements more difficult to obtain. There was no challenge recruiting the remaining 48 participants in the architecture studio swing space. Because of the close network within the college of architecture, many outside people assisted in gathering people to volunteer to take the test. A total of 58 participants were selected to take the test. These students were required to be at least 18 years of age and English-speaking. No compensation was offered for participating and students were required to sign a consent form prior to taking the test.

Figure 3.3.1 and Figure 3.3.2 indicate the test setting. The testing spanned over the course of three weeks and took place sporadically throughout the day. The testing dates were from March 7th, 2017 – March 27th, 2017. It was only possible to test one participant at a time given the equipment availability.

3.4 Testing Procedure:

A step by step procedure breakdown can be seen in Appendix II. Due to the limitation of time, testing was done in two locations. After the initial day of testing, the location and testing equipment was altered for ease of recruitment and set-up. Day one (participant's #1-10) took place in Weigal Library at Kansas State University. This data was taken using the infiniti systems. The remaining tests were conducted at APD West, the Kansas State University's alternative studio location for architecture students. The availability of students at APD West allowed for easy recruitment of participants. The inability to transport the infiniti systems to APD West influenced the decision to switch to testing the biophysical data with the E4 Empatica.

Once participants arrived, they were given the experimental results sheet Appendix I, the consent form Appendix III and the briefing statement Appendix IV. Following the completion of the paperwork, participants were fitted with either the infiniti systems or the e4 empatica wristband. They were then asked to sit for two minutes to collect baseline data. During this time frame, short simple conversation was exchanged with the participant.

After the baseline data, the biofeedback systems were time stamped, and the participant was asked to put the oculus on and adjust for clarity. Once the goggles were properly fitted, the participant entered a three dimensional movie theater where the stress inducing movie, "It Didn't Have to Happen" was played. The video duration is approximately 13 minutes long. After the movie ended, the watch was time stamped and participants were asked to report a second perceived stress level following the stress inducing portion of this test.

Next the participant enters in to the stress recovery portion of this test. The watch is stamped again and they are asked to walk around the virtual environment for approximately 10 minutes. The participant is told that they can stop and look around and take their time in the environment but they must stay on the designated path. During their time in the video, quotes and comments were collected from the participants. Many participants failed to honor the rule of staying on the path. After the 10 minutes, the final perceived stress level was reported. After the test ended, participants were thanked for their time.

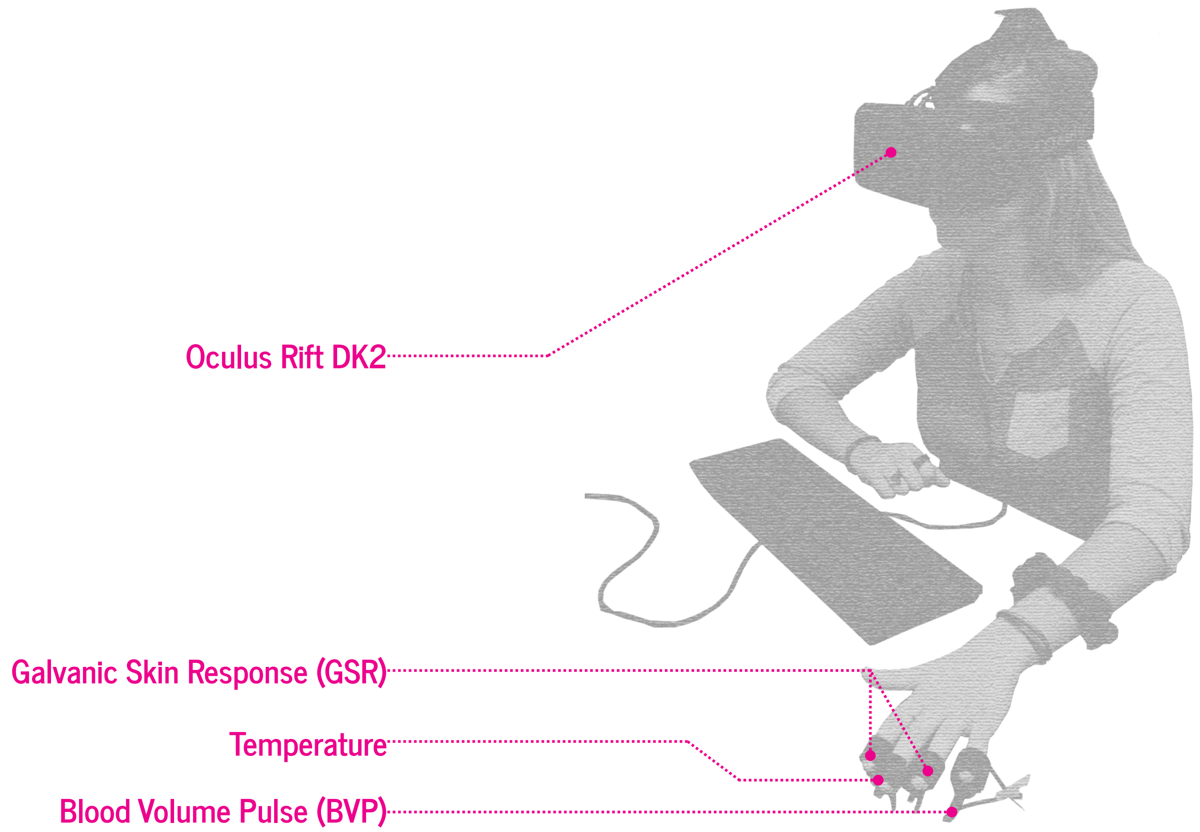


Figure 3.4.1: Testing Day 1 and birometric data.

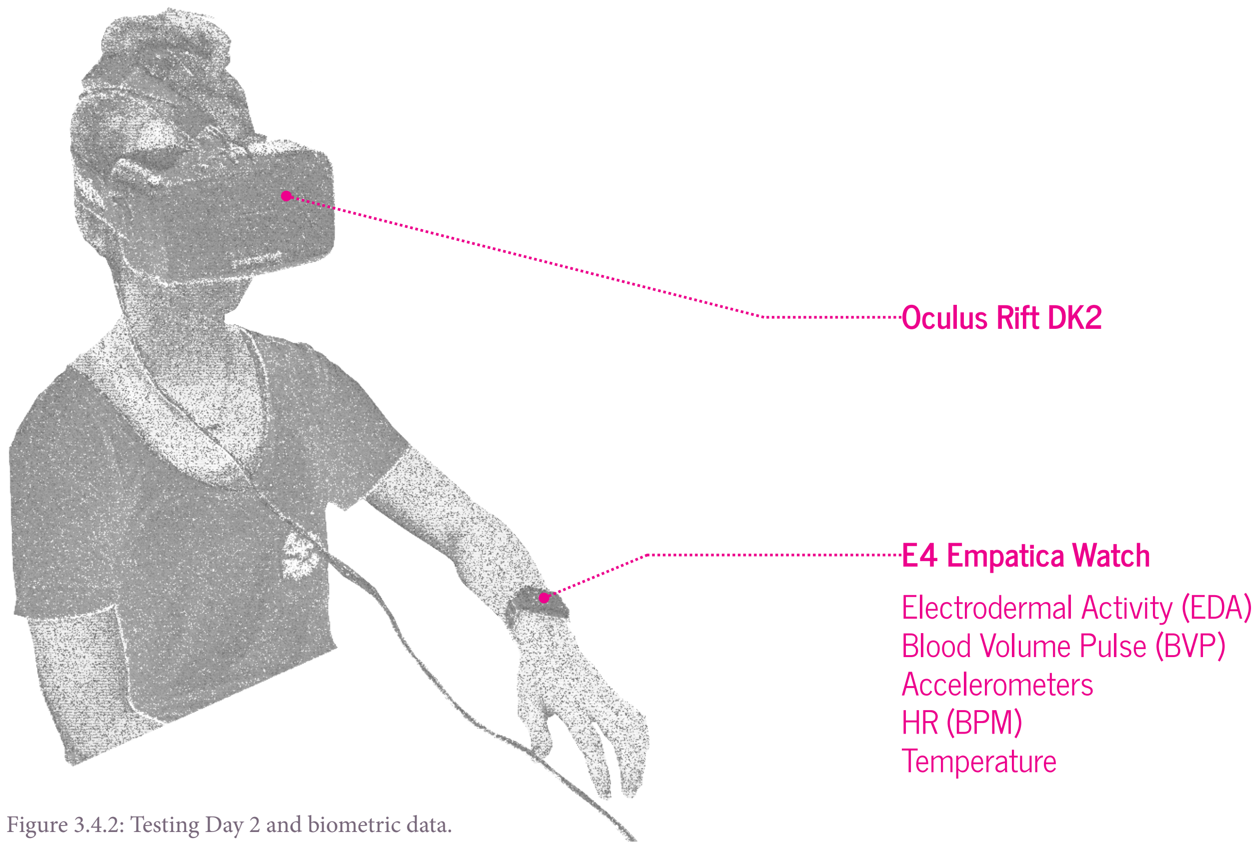
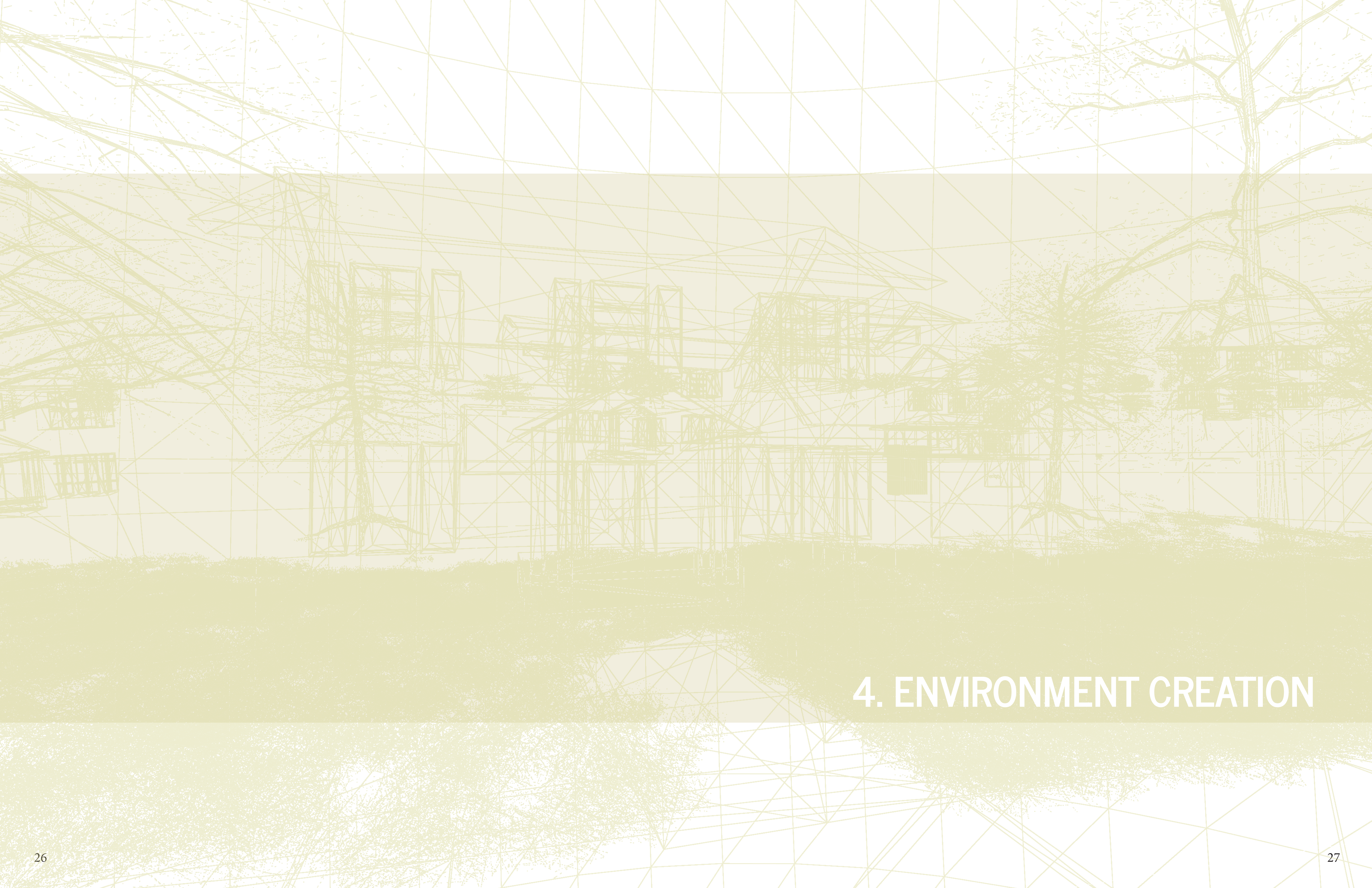


Figure 3.4.2: Testing Day 2 and biometric data.



4. ENVIRONMENT CREATION

Environment Creation

Environments were created for testing purposes and therefore do not mimic real places. In order to create a fictional place ideal for the specific task, different software was necessary. After thoroughly researching the programs available in 3D modeling, Unreal Engine 4 was selected. Unreal Engine 4, is a development platform released through Epic Games. The software runs on a simplified version of C++ called “blueprinting” which programs the game by using a series of connectors. For those familiar with C++, it is also possible to develop the game using Microsoft Visual Studios. Generally speaking, a single software does not have the capabilities needed to create an entire 3D model from the ground up. Unlike most programs, Unreal Engine 4 is capable of this; however, other programs are more narrowly focused on specific tasks and can help smooth out the process of building a 3D model. One such example is World Machine, a 3D terrain generation tool. World Machine was necessary in this project to create smooth realistic looking terrain. Many UE4 users promote World Machine on the online forum and provide useful tutorials on importing the software into UE4. One of the most powerful aspects to Unreal Engine 4 is the community involvement. Many UE4 users feel obliged to “give back” to the community. As a result, they release free assets and tutorials to the community. In developing these environments, these assets were absolutely critical to learning the program as well as to create the best final renderings possible. Figure 4.2 displays assets used in the development of this game and the name of the UE community member who released the asset.

Project Title	Release Date	Username	Assets Used in Environments	Adaptation to assets
Cinematic Grass Project	Jun-15	AaronWith2As	Supergrass #1-5 (Mesh)	Assets height, windspeed, and colors were changed
			Modular Housing (Mesh)	Houses seen in project were adapted and then combined to a single mesh. Materials were then altered.
			Sidewalk Inst (Material Instance)	Material blueprint altered. Scale and rotation changed.
			AdvancedWindBP (Blueprint)	N/A
[Free] Trees Library	Apr-14	Liu	Acacia- Acacia_02_LOD0, Acacia_04_LOD0	adapt LOD, Change LOD group, and adapt wind speed
			Beech- Beech_04, Beech_B_02, Beech_B_03, Beech_B_05	adapt LOD, Change LOD group, and adapt wind speed
			Birch- Birch_01, Birch_03, Birch_B_05	adapt LOD, Change LOD group, and adapt wind speed
			Elm- Elm_01_LOD0, Elm_05, Elm_b_03	adapt LOD, Change LOD group, and adapt wind speed
			Maple- Maple_05, Maple_B_05, Maple_B_05	adapt LOD, Change LOD group, and adapt wind speed
			Pine- Pine_02, Pine_B_04	adapt LOD, Change LOD group, and adapt wind speed
[Free] Foliage Starter Kit	Mar-14	Fighter5347	Grass Material	Paint dirt connected to blueprint on personalized terrain

Table 4a: Adapted assets used in project by Unreal Engine community alterations made.

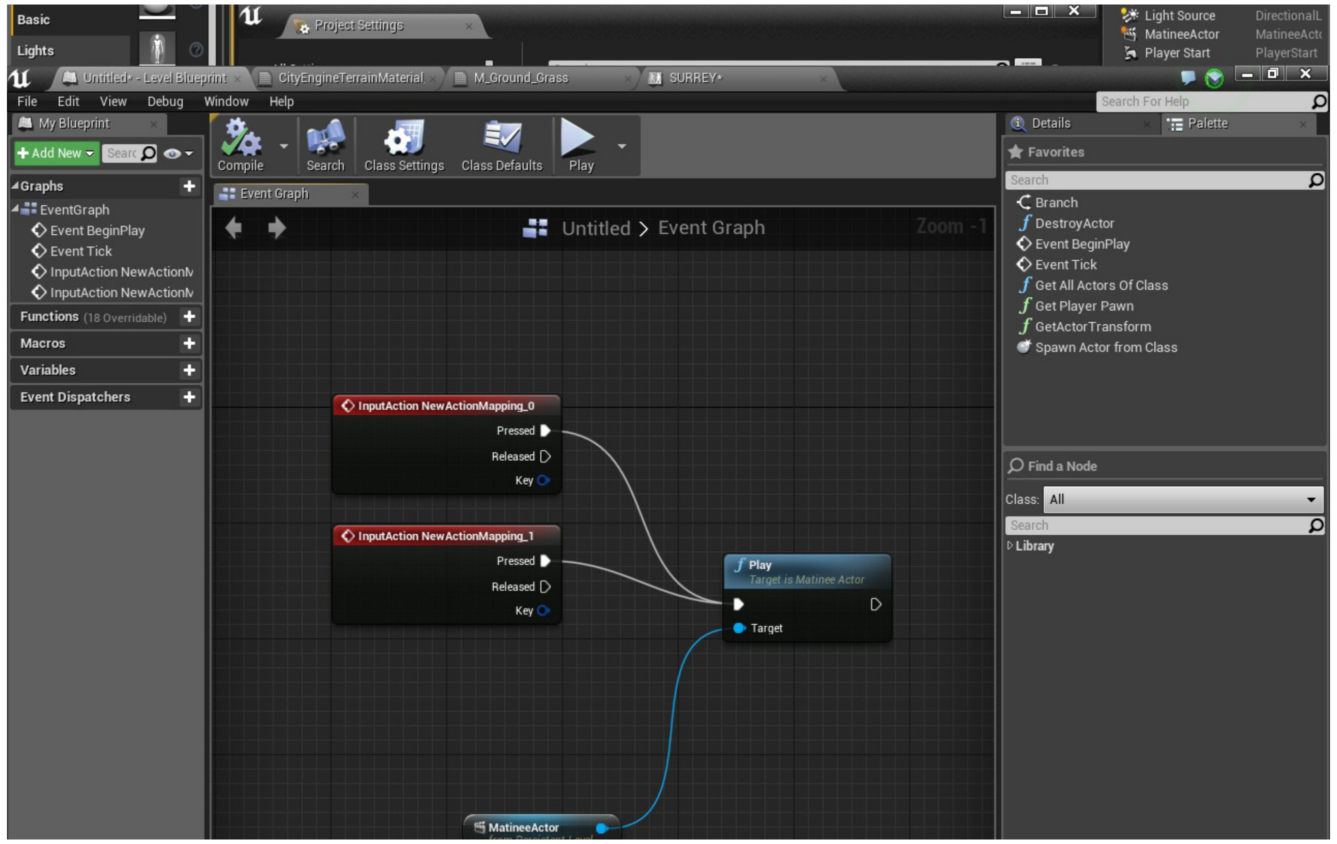


Figure 4b: Example of blueprint system used in unreal engine 4

4.1 Terrain

While terrain can be modified and sculpted within the Unreal Engine editor, it requires a lot of skill and practice to model the terrain realistically. Fortunately, UE4 provides the option of uploading a heightmap for the landscape. It is important to note that in this exploration, it was found that heightmaps are best imported when using .r16 files.

As mentioned previously, many Unreal Engine 4 users readily promote the software, World Machine. World Machine is a 3D terrain modeling tool that generates custom terrain. Using a system similar to Unreal Engine's blueprints, world machine does not require the user to have prior knowledge of code (see Figure 4.1.2). A user has complete control over terrain customization and can specify if they would prefer gentle sloping hills or steam mountains. In addition, material can be applied to a specific slope percentage. Once different materials are assigned, they can be imported individually in to Unreal Engine. A tutorial for the terrain creation can be seen in Appendix V.

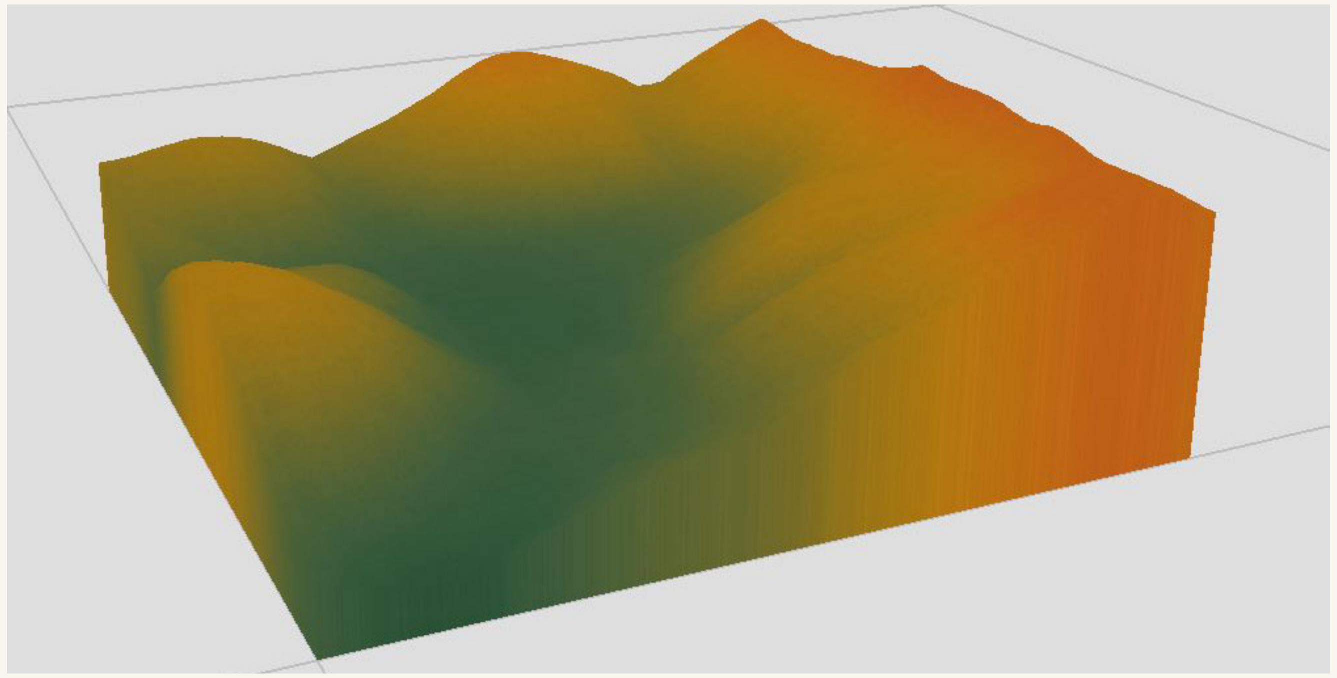


Figure 4.1.1. World Machine 3D terrain model.

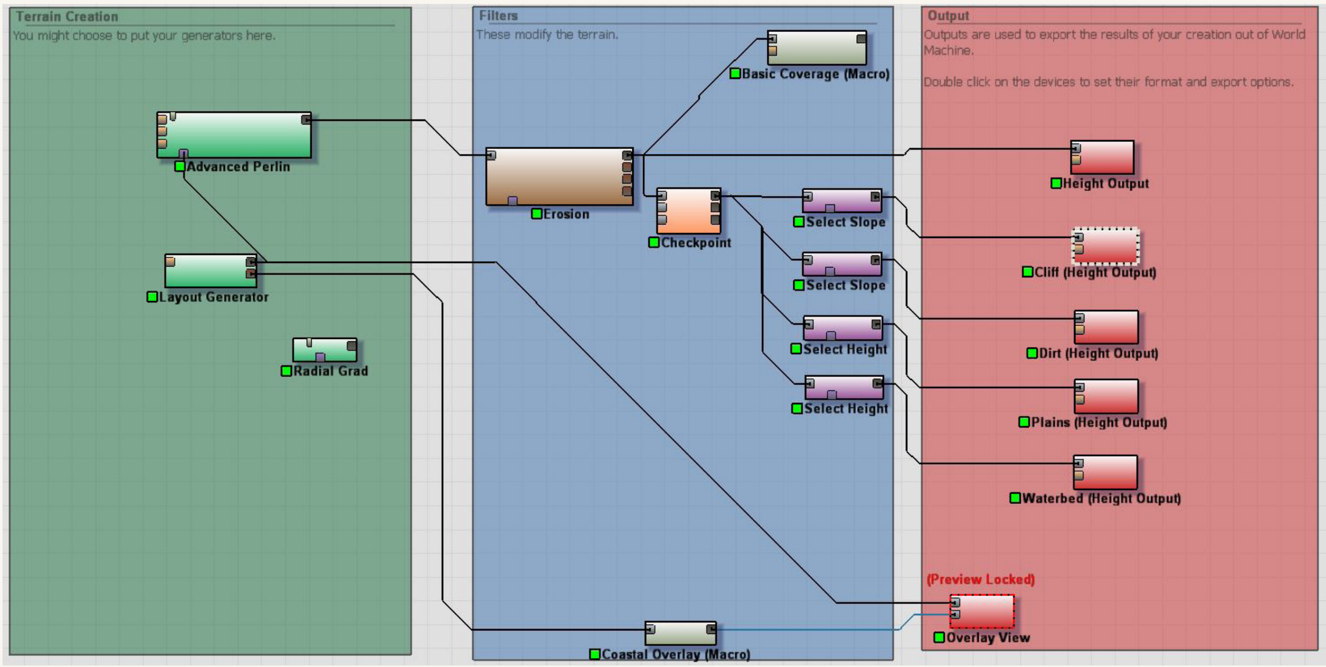


Figure 4.1.2. Connectors from World Machine.

4.2 Landscape Creation

After creating the terrain in World Machine, the model should be exported as a .r16 file and is then ready to be imported in to Unreal Engine 4. Under mode>landscape, there is an option in Unreal Engine to upload a terrain from file. The .r16 file should be imported (see tutorial in Appendix V) The landscape will automatically upload with the preset world terrain material. In order to change this the material should be selected and assigned.

A simple grass material from the starter content was applied for environment 2. In Environment 1, a material from Fighter5347's foliage starter kit was used (Fighter5347 2014). This material is blueprinted so you are able to paint material directly on the landscape. This was useful for creating the dirt path in Environment 1. The material under the paintbrush tab is converted to a landscape layer that can be painted on the terrain Appendix V.

Figure 4.2.1. Dirt Trail Painted on Terrain.

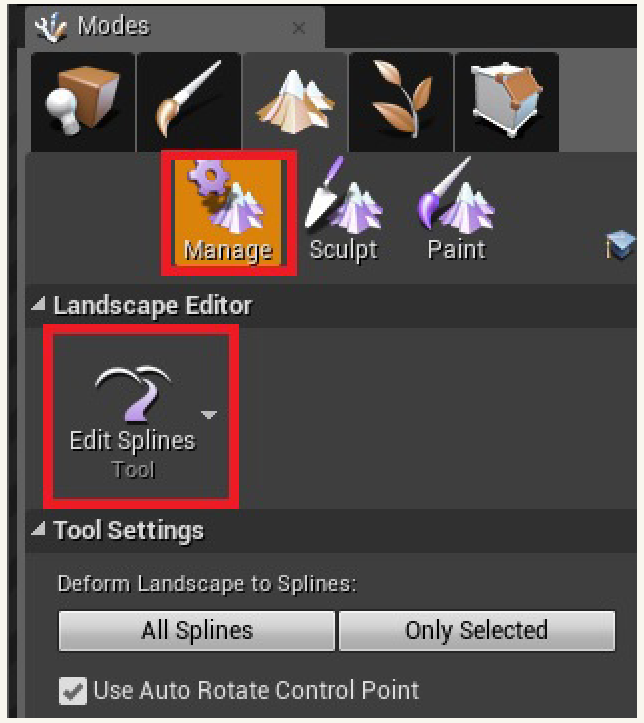


Figure 4.3.1 Landscape Spline tool.

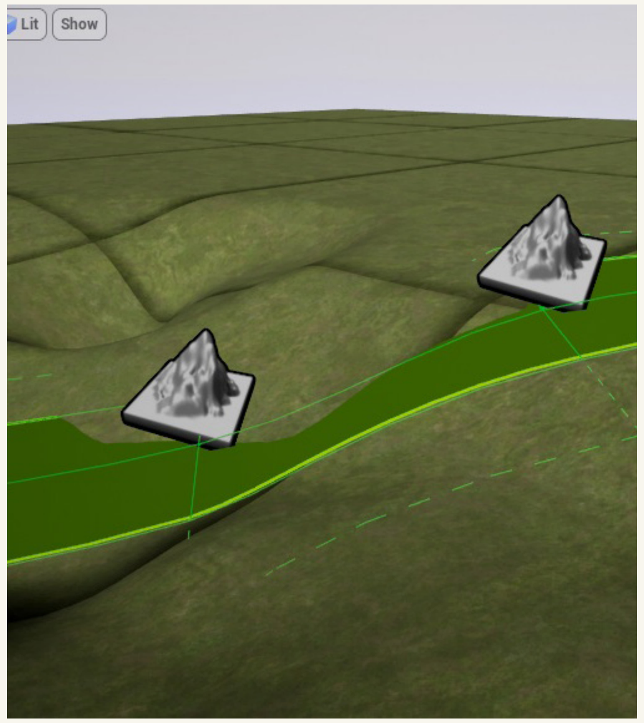


Figure 4.3.2 Landscape Spline tool.

4.3 Road Creation

In the landscape mode tab, there is a feature called splines. This feature can be used to create paths and roads. Once landscape splines are placed, there is an option to fit landscape to spline. Once clicked, the landscape will conform to fit the desired curvature of the roads. The developer can further customize the splines in details tab which allows them to manipulate the size of the spline as well as the fall off distances. This method was used in the creation of this project. However, it should be noted that this tool seems to have some problems and sometimes the splines will disappear underneath the landscape. In this case, the splines can be manually moved to the desired point.

After the splines are place, it is necessary to apply a mesh to the spline, Appendix VI. In this particular project, this step became frustrating as the mesh did sit on the spline as desired (see Figure 4.3.3). Due to time constraints, it was not possible to resolve this issue. Many UE community members expressed preference in using outside programs to create the desired paths.

Figure 4.4.1. Cinematic Grass Project. *Source: AaronWith2as*

Figure 4.4.2 Free Tree Assets. *Source: Liu*

4.4 Foliage

A unreal engine user with the account, "Aaronwith2as" created a beautiful model called the "Cinematic Grass Project." The user released this project to the public for free usage (AaaronWith2as 2015). While many assets were used from this project, (see Figure 4.1) the grass from this project was one of the most useful assets. A free tree asset from Liu was also used in this project (Liu, 2014). The trees from this project are extremely realistic and stunning. The only alteration to the trees were the LOD (level of detail) settings.

Foliage meshes can be dragged directly from the content browser into the foliage mode. In the foliage mode settings, the parameters can be altered to change the size and color distribution of the foliage type. Each type can be selected individually or as a group to be painted on to the environment. This tool can be somewhat problematic as it is hard to determine the right density. The density numbers did not seem to correlate directly with the paint brush. It is unclear whether or not this is a glitch in the engine or some underlying setting. When using a large paint brush with a high density, the program often crashed or had significant lag. For example, in this project a brush size set to 8000 at a 2.0 density took over 8 hours to render into the model. Depending on time and work flow, it is important to adjust accordingly.

4.5 Development

In June of 2015, an Unreal Engine user, "AaronWith2As" released the project "[FREE] Advanced Cinematic Grass Blueprint with 3D Imposter Sprite foliage" to the Unreal Engine community forum (AaronWith2as 2015). This project was very useful in creating the environments for this experiment. All houses in Environment 2 are iterations of the houses in the Advanced Cinematic Grass Blueprint.

In the original project, the housing units were individual pieces. In order to create one entity, each piece was individually selected, then grouped. Once grouped, each asset can be converted into a single mesh. Following this step, the mesh must be migrated over to the personal project. Materials on the houses were changed to create variation and prevent user from getting bored. However, there is still little variation in the houses. Given more time, this would be an easy fix.

Figure 4.5.1: Original House. *Source: AaronWith2as*

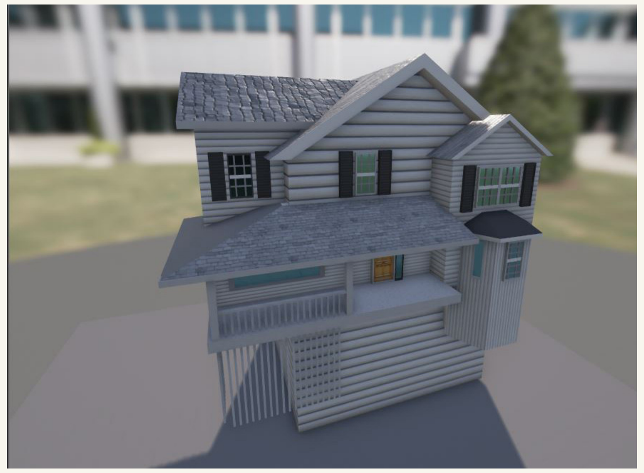


Figure 4.5.2: House Iteration Example.

Figure 4.5.3: House Iteration Example.

Figure 4.5.4: House Iteration Example.


Figure 4.6.1. Environment 1 Model with lighting through trees.

4.6 Lighting

Having little background on computer programming, lighting was a particular challenge in this project. Getting the lighting correct was complex and challenging as there are many parts. In order to get the lighting right, it was necessary to scrutinize existing projects. The lighting settings in this project are very similar to those in the cinematic grass project. While the following subgroups of the lighting section will discuss the types of light in this project and the settings selected, it is important to note that lighting is very complex and project settings and rendering settings play a very important role in getting the lighting settings right.

4.6.1 Directional light

A static directional light was selected as the main light source in this model as it is the ideal option for simulating sunlight. A directional light source is "infinitly far away [meaning] all shadows casts by this light [are] parallel" (Unreal Engine). Choosing a static directional light is important in VR in order to prevent performance costs. By avoiding settings with high performance costs, latency in the final rendering will be significantly reduced.

Under the details tab, there are several categories that can be manipulated under directional light. One of the most important categories is the Cascaded Shadow Maps. In this tab, you can determine how far in the distance the shadows can be seen as well as how close the shadows become dynamic. This is especially important in preventing a performance hit.

Another option in this category is turning on Ray Traced Distance Fields. Ray Traced Distance Fields keep shadows off in the distance looking realistic. For settings see Appendix IX.

4.6.2 Skylight

According to Unreal Engine's documentation, "the skylight captures the distant parts of your level and applies that to the scene as a light" (Unreal Engine). Appendix X displays the skylight settings used in this particular model.

4.6.3 Skysphere

The skysphere is directly connected to a light source in your model. (In this case this would be directional light). The skysphere encompasses your entire model and serves as boundaries for your lighting settings. The settings for the skysphere can be seen in figure Appendix XI.

4.6.4 Atmospheric fog

Atmospheric fog is especially important in creating outdoor environments as it gives the illusion of air density. This setting is also useful as it can mask objects in the distance which prevents rendering computation which can ultimately reduce latency. Settings for atmospheric fog density can be seen in figure Appendix XII.

4.6.5 Exponential Height Fog

Exponential Height Fog allows developers to control the fog density at a desired altitude. The settings for this model can be seen in figure Appendix XIII.

4.7 Creation Summary

Learning unreal engine was a challenging introduction to the world of computer programming. By combining a landscape architecture design background with a preliminary understanding of computer programing, renderings were able to take an entirely new level of realism that is uncommon in landscape architecture renderings. Though the environments were completely conceptual, Unreal Engine 4 provided the capabilities to create a new and unique environment.

In the end, unreal Engine 4 produced a beautiful virtual environment accompanied by high quality renderings. Getting the environment to look this way was extremely challenging and required patience and attention to detail. However, once understanding the program operations and basic computer programming terminology, everything began to seem quite simple. The learning curve and problems with the software can be frustrating but once understood, Unreal Engine 4 opens up many possibilities. This software, though relatively young and somewhat glitch has the ability to produce extremely realistic and high quality graphics. As this software develops further and the glitches are accounted for, the possibilities are endless for video games as well as the profession of landscape architecture.

Figure 4.7.1. Environment 1 Model near water.

Figure 4c Environment 1 Perspective. *Source: Vallo*

Figure 4d. Environment 1 Perspective.

Figure 4e. Environment 1 Perspective.

Figure 4f. Environment 2 Perspective.

Figure 4g. Environment 2 Perspective.

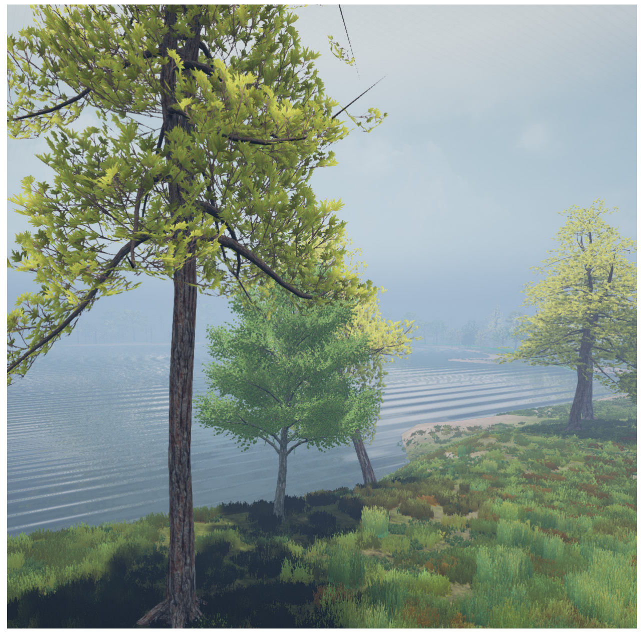


Figure 4h. Environment 1 Perspective.


Figure 4i. Environment 1 Perspective.

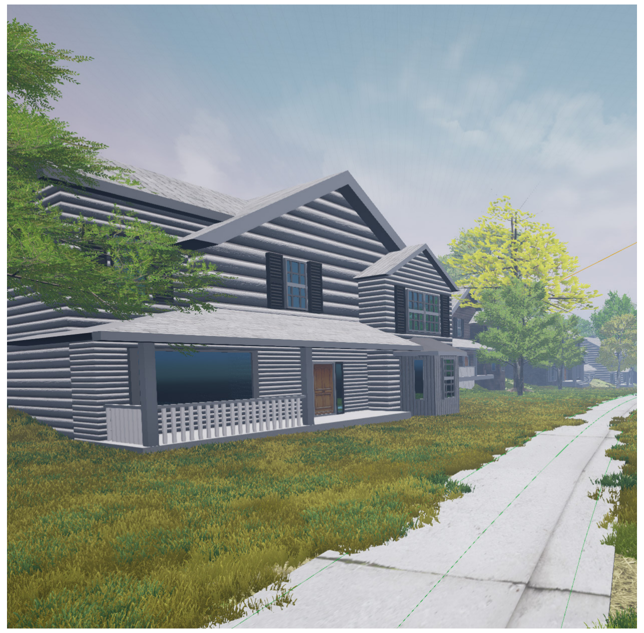


Figure 4j. Environment 2 Perspective.


Figure 4k. Environment 2 Perspective.


Figure 4l Environment 1 Perspective.

Figure 4m. Environment 1 Perspective. *Source: Vallo*

5. RESULTS

	Environment 1	Environment 2	Control Group	Combined
Number of Participants	28	15	15	58
Gender	40% M, 60% F	67% M, 33% F	53% M, 47% F	50% M, 50% F
Average Age	22.5	23.86	22	22.72
Initial Stated Stress (Mean)	2.54	2.6	2.6	2.56
VR Experience (Y/N)	50% Y, 50% N	93% Y, 7% N	67% Y, 33% N	62% Y, 38% N
Post Video Stated Stress (Mean)	3.18	2.3	N/A	2.87
Post VR Stated Stress (Mean)	1.34	1.43	1.7	1.48

Table 5.1.1 Population Sample.

Results

5.1 Participant Information

Fifty-eight people participated in this test. The participants for this study were 96% university students and 4% non-students. The study sampled exactly half female and half male participants. The average participant age was 22.73. Twenty-eight participants were tested in Environment 1. Fifteen participants were tested in Environment 2, and 15 participants were tested in an intervention study. The majority of students were in the College of Architecture, Planning, and Design at Kansas State University.

Prior to the actual test, participants reported their demographics information, as well as, answered other questions pertaining to their individual lifestyle habits. This survey included information regarding the individual's level of empathy as well as anxiety Appendix I. One of the most valuable pieces of information reported during this test was the perceived stress level. The perceived level of stress was reported three times during the testing procedure; before, during, and after and will be discussed in detail in the following sections.

5.1.1 Environment 1

Environment 1 sampled 28 participants. The participants were 40% male, and 60% female. The average age amongst participants in Environment 1 was 22.5. Exactly half of the participants in Environment 1 had experienced virtual reality prior to taking this test. The average initial stress rating was 2.54 (on a scale of 1-5, 5 being the most stressed). The mode for initial stated stress was 3, which was reported by 9 participants. After the video, the mean reported stress rating was 3.18 with a mean of 2 and 3. Both numbers being reported 6 times each. After walking through Environment 1, participants reported an average stated stress level of 1.34. Fifteen (the majority) participants reported a stress level of 1.

5.1.2 Environment 2

Environment 2 sampled a slightly smaller group of 15 participants. Sixty-seven percent of participants for the Environment 2 group were male, 33% were female. The average age of participants in Environment 2 was 23.86. Ninety-three percent of participants in the Environment 2 group had previous exposure to virtual reality. Participants from environment 2 reported very similar initial stress levels to participants in environment 1 (mean= 2.6). The mode initial stated stress was 2, 3, and 4, each being reported 4 times. Participants in Environment 2 found the video portion to be less stressful than those in Environment 1, with an average perceived stress level of 2.3. The most occurring number in this stated stress report was 2. After the VR, participants reported stress levels to be 1.43.

5.1.3 Intervention Group

Participants in the intervention group did not watch the video. Instead the group was given the treatment (VR) portion of this test following the two minute baseline. Fifteen participants were sampled in the intervention group. Of these participants, 53% were male, and 47% were female. The average age of participants was 22 and 67% had previous experience with virtual reality. Upon entering the test, the initial stress report averaged 2.6 (exactly the same as environment 2). Six participants reported the mode stated stress of 3. Following the virtual reality, participants stated their average stress levels to be 1.7, with 6 participants reporting the mode number of 1.

5.2 Stated Stress Report

Several independent unpaired t-tests were run to see if any of the survey answers were predicative of the stated stress level. However, no test indicated statistical significance ($p<.005$). Each independent variable was run in conjunction with initial stated stress, post-video stated stress, and post VR stated stress. Contrary to the hypothesis, people who watched scary movies often rated the stressor video the same as people who did not. Additionally, people who were highly empathetic did not show a higher perceived post-video stress than those who did not rate themselves as empathetic. No other variables proved to be influential.

Additionally, a one-sample t-test was run to compare the stated stress level values from initial, post-video, and post-VR. When comparing the mean initial stated stress ($M=2.57$) to the mean after-video stated stress ($M=2.87$), $t(42)=-2.16$, $p<.05$. This indicates that the video slightly raised stress levels. Additionally, the mean post-VR stated stress ($M=1.47$) compared to the mean post-video stated stress ($M=2.87$), showed statistical significance. This t-test revealed $t(57)=-12$, $p<.001$.Statistical significance was found once again when comparing the mean after VR stated stress ($M=1.47$) to the mean pre-test stated stress ($M=2.57$). In this case, $t(57)=-9.42$, $p<.001$, demonstrating that participants in all cases not only recovered from the video, but reduced their stress levels as a whole in the virtual reality environment.

Both Environments 1 and 2 showed a statistically significant improvement in stress reduction from the video. However, participants in the intervention group also had reduced stress levels even without the video. Stress level following the video varied significantly as some people thought the video was somewhat comical. See Figure 5.5.1. However, there was statistical significance after the video in the participants in Environment 2. The other two reported stress ratings were less pronounced than in environment 1. The base report in environment 2 was not statistically significant. See Figure 5.5.2. None of the values in the intervention group were found to be statistically significant. See Figure 5.5.3.

5.3 Physiological Data

Descriptive statistics are presented in order to identify possible trends in the heart rate data collected by the E4 Empatica. Each participant's heart rate data was initially normalized on a scale of 0-1 and the average across each category was taken. The confidence interval was then computed to find the high and low values of each test. However, the final analysis normalized each participant's dataset based on their maximum heartrate. This analysis assumes the participants are all young healthy adults. For slightly more accuracy, it would be suggested that in the future participants would report their health/fitness levels.

For the most accurate heart rate analysis, an equation based on age-predicted maximal heart rate was used to normalize the data set (Tanaka et. al 2001). For males, this equation was (208.7-(.73*age)) and female maximum heart rate= (208.1-(.77*age)) (Tanaka et. al 2001). The raw heart rate values were corrected for each participant's minimum and theoretical maximum based on Tanaka et. al's equation (Tanaka et. al 2001).

The percentages were then calculated for each second of every participants data. Minimum heart rate values are not true minimums. Instead minimum values in the entire data set were used for the HR min.

Environment 1 Max HR

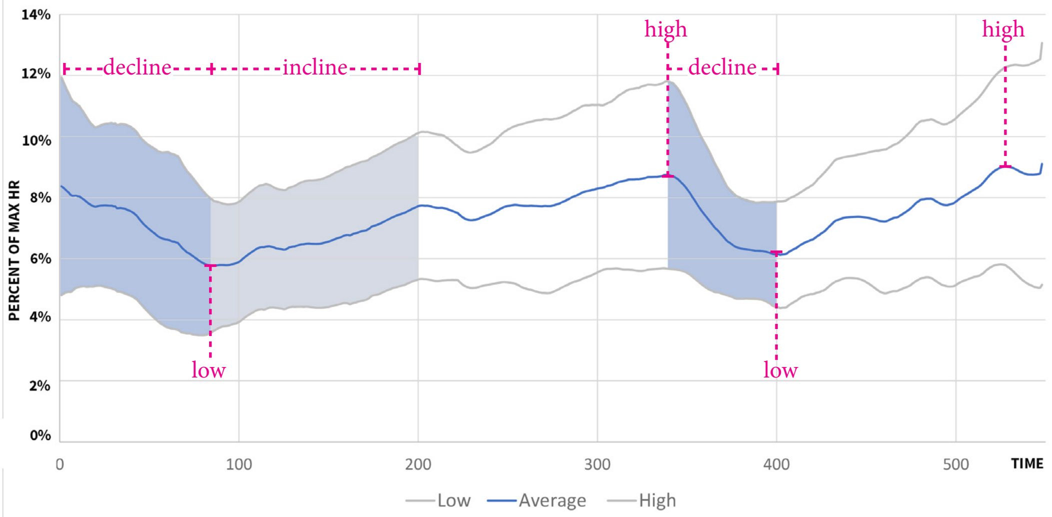


Figure 5.3.1.1 Normalized Heart rate Environment 1.

Figure 5.3.1.1 Environment 1 Max HR

The dark blue line in Figure 5.3.1.1 indicates the average (within-group) normalized heart rate percentage based on age-predicted maximal heart rate. In the first 90 seconds, a slight decline in to the low point indicates the initial stress recovery. At the two indicated low points, the confidence intervals are relatively small compared to the rest of the graph indicating a strong stress recovery response. The high points on the other hand, have large confidence intervals demonstrating a less pronounced reaction. Participants reported the urge to explore and several disregarded the rules toward the end, which may have potentially evoked a heightened response which coupled with the stated stress findings was likely a positive response.

Environment 2 Max HR

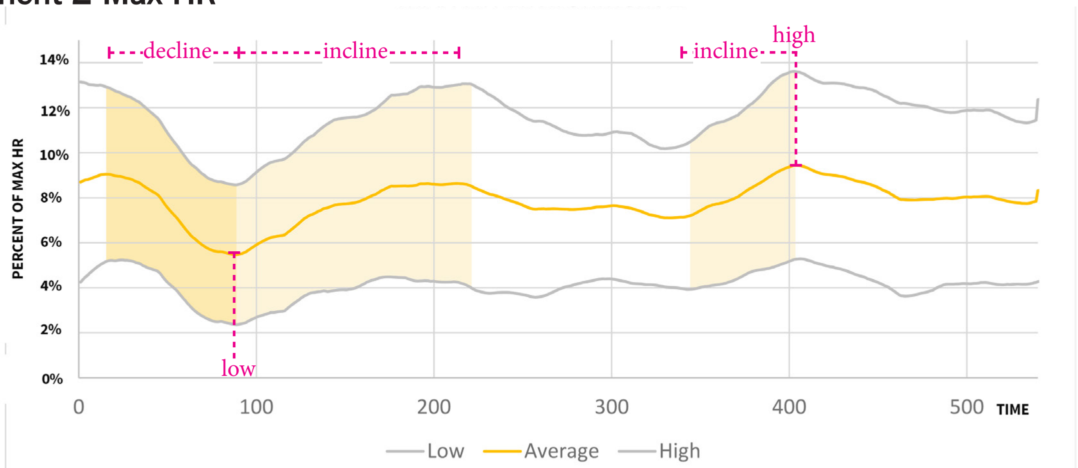


Figure 5.3.1.2 Normalized Heart rate Environment 1.

Figure 5.3.1.2 Environment 2 Max HR

Following an initial increase in HR, the same 90 second decrease seen in Environment 1 is depicted in Figure 5.3.1.2. Once participants hit this low point, their heart rates rise to a seemingly steady state. The initial increase in HR for Environment 2 may be caused by a higher degree of latency in the environment which may have delayed the HR decline. Following the initial dip in HR, participants seem to remain around the same HR as when they entered. Like Environment 1, lower points seem to have a smaller confidence interval.

Intervention Max HR

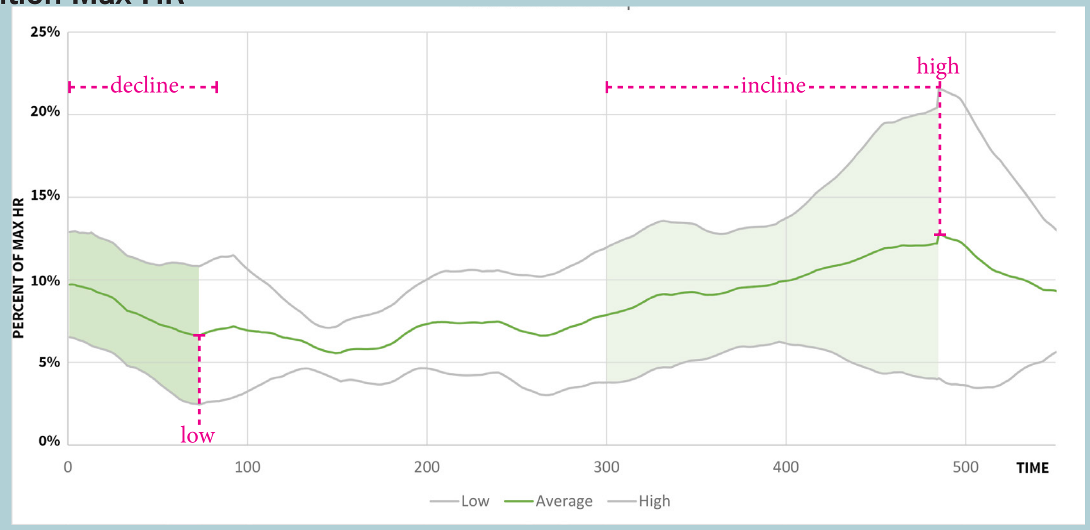


Figure 5.3.1.1 Normalized Heart rate Intervention group.

Figure 5.3.1.3 Intervention Max HR

The initial 90 second decrease is much less pronounced in the intervention group which is expected since heart rate should be theoretically lower without having just been exposed to the stress inducing video. The confidence interval at the low point is very small, indicating little variation within the data. The high point on the other hand, shows a large confidence interval, meaning there was a large amount of variation around 500 seconds.

Combined Max HR

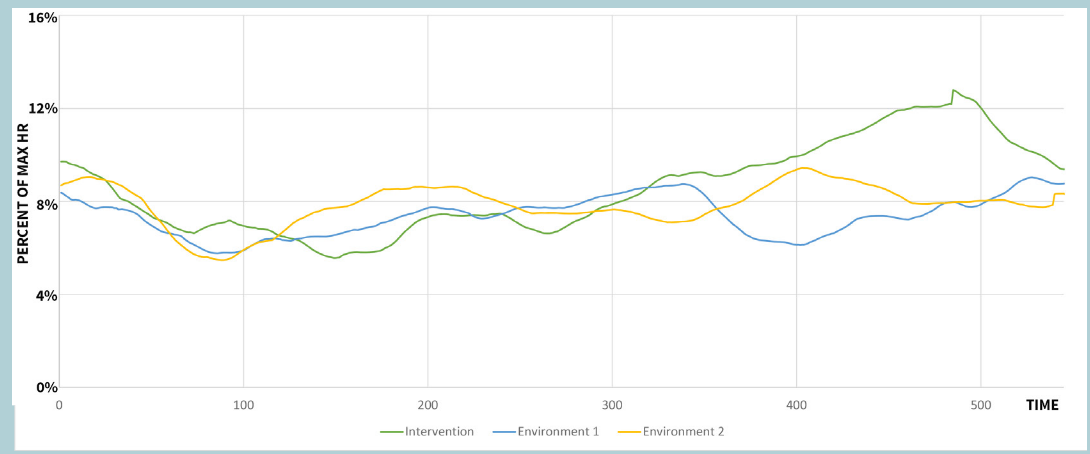
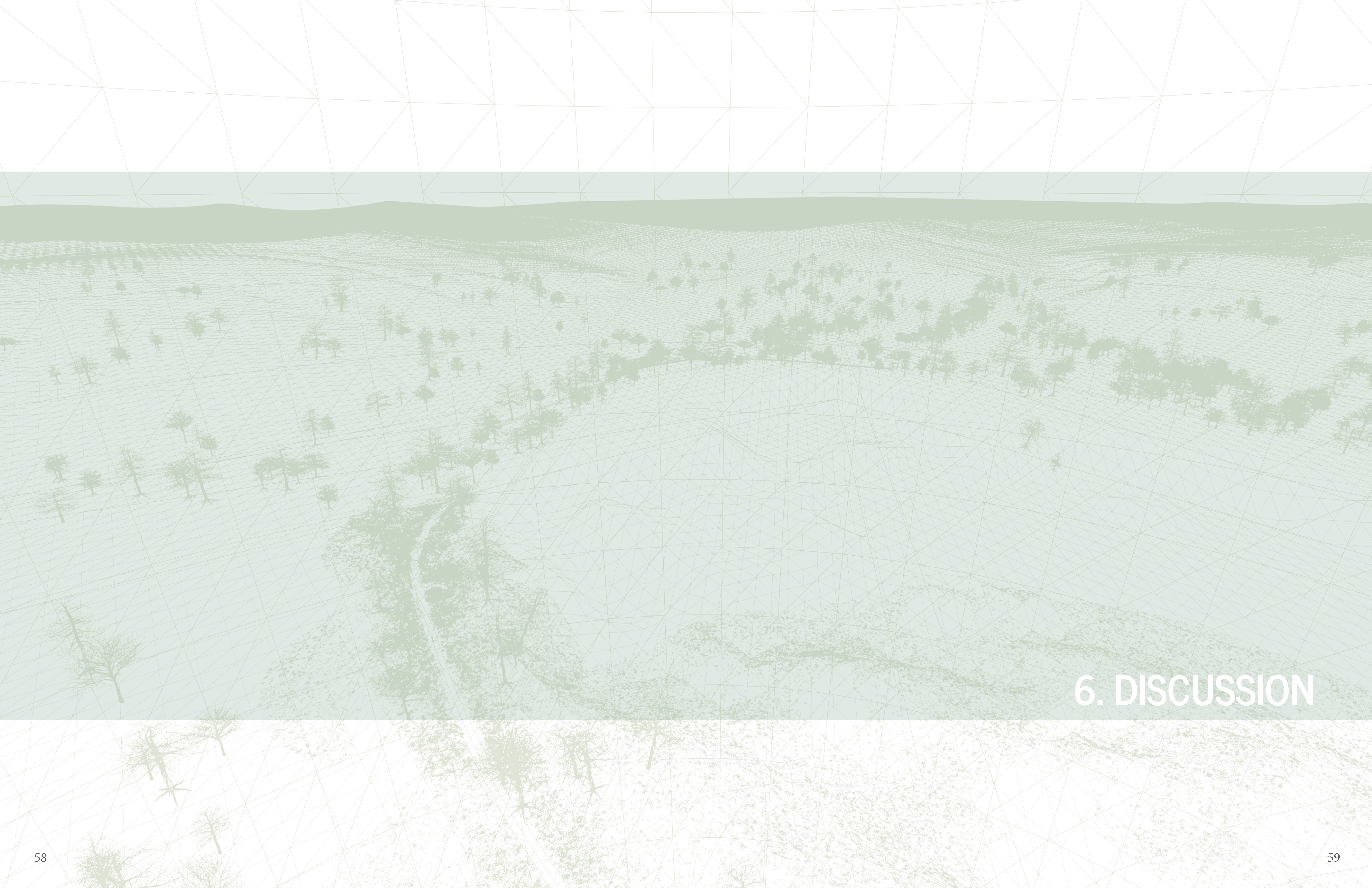


Figure 5.3.1.2 combined normalized heart rate

Figure 5.3.1.4 Combined Max HR

By combining the average max HR for each group into one graph, there seems to be a general slight decrease in HR while the averages for the rest of the environments remains steady. At about 490 seconds, the intervention group increases significantly from the rest of the group. This may be due to the large confidence interval seen in Fgure 5.3.1.3.



6. DISCUSSION

Figure 6a. Environment 1 Perspective. *Source: Vallo*

Discussion

6.1 Result Significance

As the previous chapter states, there was no significant variation between the stated stress levels in the two virtual environments. It was originally expected that participants would recover from stress more significantly in Environment 1. However, stated stress did reveal that all participants recovered from stress, regardless of the environment and regardless of the presence of the stressor. Participants effectively lowered their baseline perceived stress level to a significantly lower rate after the test. This is incredibly beneficial as it reveals that being exposed to nature in virtual reality provides significant benefits in stress recovery. To determine the extent of this effect, it would be beneficial to compare this study to one conducted on a similar trail in real life. The additional benefits of exercise and movement likely play a huge role in stress recovery in addition to the exposure to nature. Additionally, determining how uncontrollable variables in the outdoor setting may influence stress recovery in a positive or negative manor.

Additional value would be gained if this study were to include the third more industrial environment. The two environments shown had a high degree of nature and trees. There may not have been a significant enough difference in the amount of nature to create a significant difference in the results.

6.1.1 The Novelty Effect

Almost all innovations in technology produce an initial novelty effect (Walls et. al 2006). A study looking at the effect of technological novelty and perceived risk discussed that novelty is an "objective reality" rather than a "subjective response" (Walls et. al 2006). Since virtual reality is so new, it is difficult to determine how significant of a role the novelty effect has.

In the initial test design, the novelty effect was not taken into consideration. For many participants, this was their first time being immersed in a virtual world. In the pilot study, it was quickly noted that participants experienced an increase in arousal that conflicts with the attempt of determining stress recovery. In order to accommodate for this, questions about prior VR experiences was added to the pre-test. However, even though there was potentially a novelty effect, it did not predict stated stress levels. If novelty did play a role in stress recovery, it is possible it would be indicated in the EDA data. Additionally, allowing the participants to watch It Didn't Have to Happen in a virtual theater may reduce the novelty of immediately stepping into the nature environments. However, it is unclear whether this was enough to completely reduce the excitement of virtual reality. Despite the arguments for the novelty effect, the statistical analyses demonstrated no significant factor or prior exposure to virtual reality.

6.2 Environment Design
6.2.1 Time Constraints

This project operated on a very ambitious time frame. To learn an entirely new and complex software, design and create two virtual reality environments, run testing, and produce a book in two semesters was an enormous challenge. Given the workload, this project exceeded the original expectations. More time would have provided the opportunity to refine the environments and the tests. However, in this timeframe, the amount of work done was extensive and once again exceeded the expectations.

Some unforeseen events pushed the testing date back significantly which altered the ability to recruit participants and locations prior to the actual testing date. Because of this, many of the participants tested were fellow architecture students, who may experience a higher level of stress due to the extensive hours spent doing project work. While this may not be a desirable population sample, it still met the goal of seeing if the testing procedures were viable. Another result of late testing was not being able to receive the help needed to run the infiniti systems in the timeframe. This resulted in the first ten pieces of data (taken with the infiniti system) to be discarded, also prompting the switch to the empatica watch. Which made the testing much easier to be conducted single-handedly.

Time limitations also resulted in the inability to complete the third environment. A much longer learning curve was required in learning Unreal Engine 4. The program was much more complex than initially perceived. Additionally, the size of the model slowed the computer program down significantly making simple tasks take a very long time.

6.2.2 Resource Availability

It would have been much too challenging to design each 3D asset individually. Therefore, it was necessary to use the free assets created by the community members. The availability of assets on the community forum is limited requiring certain design features to be altered in the creation process. While this was a challenge and a limitation, working with the available resources was relatively simple and still produced a desirable environment. Given more time, the environment design would be slightly smaller as working with such a huge file posed many problems. Computer crashes were frequent while populating the design with foliage. Size also caused the model to run extremely slow, lighting rebuilds alone took around 30 hours.

6.3 Study Design
6.3.1 Problems with Study Design

Due to the limited recruiting time, the majority of the participants were architecture students. The school of architecture at Kansas State University is commonly stereotyped as one of the most time consuming colleges within the university. Students often experience heavy workloads, little sleep, and significant criticism on projects. Because of this, stress levels prior to testing may have been slightly higher than average. In addition, many of the high stress students reported stress recovery after watching the stress inducing video, It Didn't Have to Happen. This may have been a result of poor quality graphics or simply because taking the survey was a break in itself.

In addition to the lack of diversity in participants, the stress inducing video itself seemed to be a shortcoming in the testing procedures. In Ulrich's study, the video It Didn't Have to Happen was proven to induce stress on participants (Ulrich 1991). However, this video originally dates back to the 1960's. Since then, there has been significant improvement in horror movie production. Since people today are more accustom to the higher quality graphics, the video did not seem to consistently induce stress on participants. Furthermore, participants reported the video to have bad acting which made it somewhat comical to the participants causing them to produce the opposite reaction.

To reduce the novelty effect seen in the pilot study, the video was played in a virtual theater so the participants could get used to the virtual reality prior to entering the testing environments. Many participants were seen looking away from the movie scene and were distracted by the "design of the theater." This was specifically seen in the architecture as they have an enhanced interest in the built environment. For example, one participant (in the college of architecture) noticed, "there are no fire exits in this theater." The theater may have also been the first experience of virtual reality for participants prompting natural curiosity to look around the theater. This also may have caused a novelty effect.

6.3.2 Perceived Stress Level

Some of the validity for perceived stress level may have been compromised due to the inconsistency with the written survey portion and the actual reported results. Students did not recognize the scale when asked to audibly report their perceived stress level. Since multiple students were not tested simultaneously, the perceived stress level could have been changed to a scale of 1-10 as this would have provided an opportunity to demonstrate a greater range of stated stress levels. However, the study procedure was somewhat unpredictable and the stress scale remained at 1-5.

6.3.3 Testing Environment Issues

Once again, the testing for this experiment was done very last minute preventing some of the fine tuning issues to be worked out. Because it was not possible to reserve a room prior to receiving an accepted IRB, the testing took place in a very informal environment <See figure>. Due to the informality of the environment, many participants seemed to lose focus. Additionally, since architecture students spend a lot of time in the architecture studio building, many people are comfortable and familiar with each other. Curiosity and conversation was common from non-participants while the testing procedure was happening

6.4 Virtual Environment Issues

Since virtual reality is a relatively new technology, the equipment is rapidly being redesigned and updated. The available equipment, Oculus Developer Kit 2 was not the best equipment on the market. This made it a challenge in producing latency and frame skipping. Unfortunately this caused some students to have slight simulation sickness in the environments. Since E2 had significantly more assets than E1, the latency and frame skipping was much worse in this environment. This makes it somewhat difficult to determine whether or not there was an effect on stress levels. More participants reported feeling dizzy or having headaches after going through this environment.

Another issue with Environment 1 versus Environment 2 is that Environment 1 was much more refined than the second environment. E2 was significantly more challenging to build and the increased amount of assets made it difficult to get the environment entirely refined before testing. Additionally a full lighting rebuild was not possible on E2 prior to testing. So some objects may not have reached their full lighting potential within this environment.

During the test, participants made some very valuable points that should be considered in future testing. One of the most frequently reported comments was "the absence of people makes the environment somewhat creepy." The presence of people in the environment was discussed during the design process. However, given the lack of prior knowledge of the 3D modeling program, it would have been challenging to create realistic animations of virtual people. Thus more research should have been conducted on the stress impact of solitude.

Several people reported that the inability to run and explore the environment to be stressful. Though people were asked to remain on the path, many ignored this rule and veered off. Those who did not often reported a strong desire to explore distant objects off the path.

Other comments made during the testing procedure involved the lighting. Participants seemed to enjoy looking up at the sun shining through the trees and found the shaded areas to intriguing. However, two participants made comments on the amount of fog in the environment which may have given it a slightly ominous effect.

Fewer participants than expected reported using their time in the environment to think about their outside obligations. Several actually reported that in the environment they completely forgot about how much they have to do.

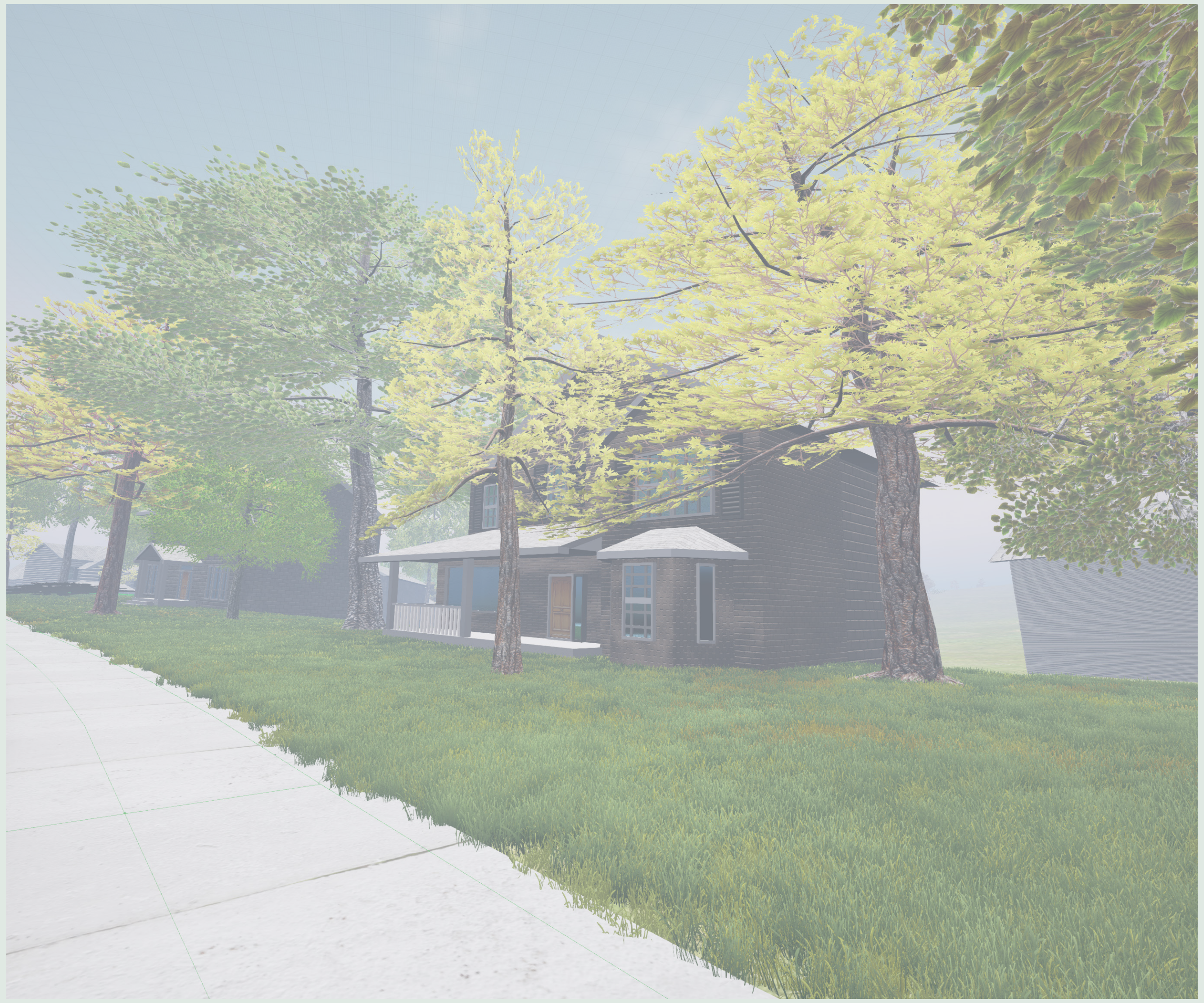


Figure 6b. Environment 2 Perspective. *Source: Vallo*

Figure 6c. Environment 1 Perspective. *Source: Vallo*

6.5 Lessons Learned

The entire testing procedure served as a learning process. Many opportunities were missed as they were not considered prior to testing. Because the timeline was extremely ambitious, the small details were not nearly as refined as they should have been. The learning curve for producing a virtual environment was much slower than expected and what would have ideally taken two months actually took about five.

The benefit of testing a study in Virtual Reality is that it allows for a completely controlled environment. However, the actual testing environment was distracting and added many unpredictable variables into the procedure. These variables were somewhat included in the analysis. However, time prevented thorough analysis of these details. Remaining formal was incredibly challenging in the given environment and much would be altered in future testing.

Being realistic with time constraints was another important learning lesson during this project. This project was extremely ambitious given the time constraint of the project. Learning how to model virtual landscapes could easily be its own project in itself. Adding the testing procedure and data analysis was a lot of work. Without having run an experiment, there would be more opportunity to explore virtual reality and its implications in landscape architecture.

Since this was the first time conducting a study of this manor, much knowledge was gained in respect to procedure refinement. Every detail plays a major role in the validity of the data collected. Simple mistakes during the testing procedure could have been prevented and the data sets would have been more accurate. Many design iterations were necessary to prevent data discrepancy between the two environments.

6.6 Future Considerations

Because there were so many shortcomings in the testing procedure, it is recommended that this study would be replicated and reproduced in a refined manor. The majority of these shortcomings are easily fixable. Given more time, it would be extremely beneficial to work with someone more proficient in Unreal Engine 4. Latency reduction would be especially beneficial in this respect.

The environments tested were much more geared to the amount of human intervention as opposed to the amount of nature the participants were exposed to. Since no trees were added or removed between environments, it could be argued that the degree of nature participants were exposed to was the same amongst the two testing environments. Changing the environments to be more fitting to the actual question would be ideal.

Figure 6d. Environment 1 Perspective. *Source: Vallo*

Figure 6e. Environment 2 Perspective. *Source: Vallo*

6.7 Real World Application

6.7.2 Virtual Reality

Landscape architects currently relay on plan graphics and perspective images to portray designs to their client. While the landscape architects themselves are educated in these image types, the client often is not. Many clients may not be able to spatially interpret plans. Perspectives, are often a good indicator of the space. However, they only encompass a small area of the actual design. Clients are not able to fully experience a design and understand the space prior to it being built. By implementing virtual reality into landscape architecture, clients will be able to fully see and experience a design prior to the site being built. This in turn would allow the client to understand the space and hopefully increase their ability to articulate problems and reduce communication issues between the designer and the client.

Additionally, even landscape architects themselves often have a hard time fully understanding a space. The future of virtual reality allows designers to manipulate spaces in real time while fully immersed in their own design. This opens many doors and will allow for more refined designs in the future. This same idea would be especially beneficial in landscape architecture education. By familiarizing students with actual dimensions of space, they will likely have a better understanding of sites and spaces.

6.7.3 Stress Recovery

Finding out how much nature is needed to quickly recover from stress, gives designers, public health officials, and even government officials a better insight on mitigating stressful environments. As already stated, stress plays a negative role on our overall well-being. If the findings of this study are consistent with the hypothesis, places with high instance of stress can not only better understand how to reduce stress but can use similar techniques such implementing virtual equipment.

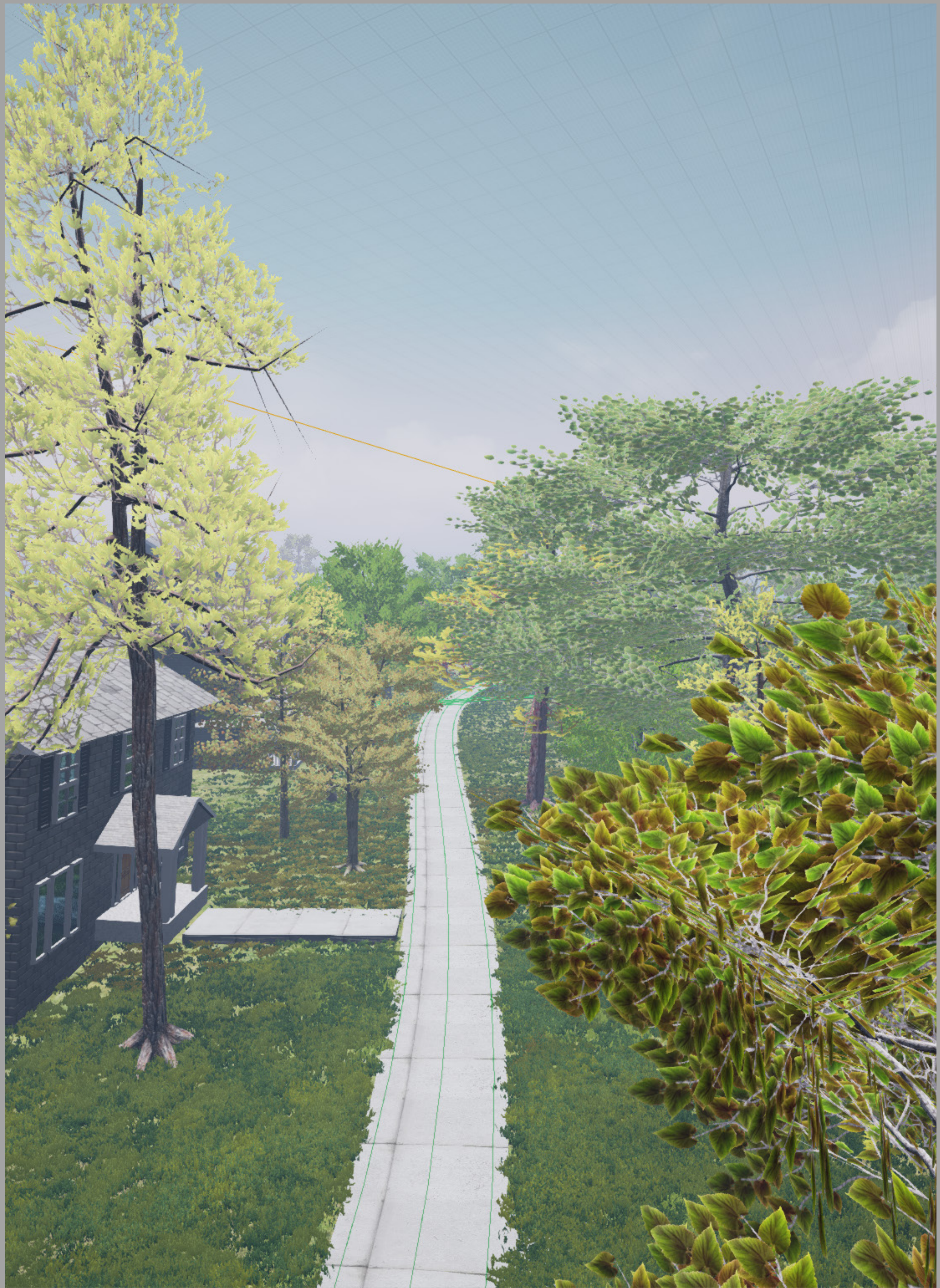
6.7.4 Public Health and Outdoor Recreation

This study is especially useful for those in design. In any case, understanding how people respond to different environmental elements is key to designing places that emphasize human experience. Knowing what elements reduce stress can be a design investment for schools, offices, and other similar places. More wild and outdoor settings can use these ideas for trail design and placement of facilities and other amenities

6.7.4 Virtual Reality and Technology

As for using the virtual environment, this is a technology that can be easily installed into an office or other places. This research contributes to the endless possibilities of virtual reality and shows how it can be used in ways that exceeds normal use of video games and entertainment. Unlike real wilderness experiences, virtual reality opens doors for people who couldn't experience the great outdoors otherwise. For example, those who are unable to walk cannot fully immerse themselves in backcountry wilderness as it is inaccessible. However, virtual reality provides the opportunity for people to go places they could have never experienced otherwise. While the future of virtual reality is unclear, this is a product that has endless potential.

7. CONCLUSION



7. Conclusion

In conclusion, this study was able to show that regardless of which group participants were in, stated stress levels improved significantly. With this knowledge, it is beneficial to continue researching stress recovery in virtual reality environments. It is recommended that future testing analyzes a larger sample group and uses a more refined testing procedure and location.

Another finding from the study was the initial heart rate drop following the first 90 seconds of the video. It is uncertain why this drop occurred. Further analysis of the biophysical data may help indicate the cause of this drop.

As the future of virtual reality grows, the technology will become more available and more refined. Along with these changes comes the responsibility of the consumer to ensure that this technology is used as an asset, rather than an escape from social interaction. While many associate virtual reality as an escape from the real world, there are many ways it can be used in a positive manor. It is recommended that stress recovery benefits in particular are studied in further depth.

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Figures

<Figure 3.1.1> Vallo, L. (2016). Degree of Exposure to Nature Comparison [Indesign].

< Figure 3.1.2> Vallo, L. (2016). Original Environment 1 Design [Sketch].

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< Figure 3.3.1> Vallo, L. (2017). Testing location, Day 1. Kansas State University Weigal Library. [Photograph].

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< Figure 3.4.1> Vallo, L. (2017). Testing Day 1 Biometric Data. [Photoshop].

< Figure 3.4.2> Vallo, L. (2017). Testing Day 2 Biometric Data [Photoshop].

< Figure 4b> Vallo, L. (2017). Blueprint System [Unreal Engine 4 Screenshot].

< Figure 4.1.1> Vallo, L. (2017). World Machine 3D Terrain Model. [World Machine Screenshot].

< Figure 4.1.2> Vallo, L. (2017). World Machine Connectors. [World Machine Screenshot].

< Figure 4.2.1> Vallo, L. (2017). Plan of painted trail [Unreal Engine 4 Screenshot].

< Figure 4.3.1> Vallo, L. (2017). Landscape Spline Tool [Unreal Engine 4 Screenshot].

< Figure 4.3.2> Vallo, L. (2017). Landscape Spline Tool [Unreal Engine 4 Screenshot].

< Figure 4.4.1> AaronWith2as. (2014). Cinematic Grass Project [Unreal Engine 4 Screenshot].

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< Figure 4.5.3> Vallo, L. (2017). Adaptations to houses [Uneral Engine 4 Screenshot].

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< Figure 4.6.1> Vallo, L. (2017). Environment 1 Model with Light shining through tress [Unreal Engine 4 Screenshot].

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< Figure 4c> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4d> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4e> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4f> Vallo, L. (2017). Environment 2 Perspective [Unreal Engine 4 Rendering].

< Figure 4g> Vallo, L. (2017). Environment 2 Perspective [Unreal Engine 4 Rendering].

< Figure 4h> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4i> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4j> Vallo, L. (2017). Environment 2 Perspective [Unreal Engine 4 Rendering].

< Figure 4k> Vallo, L. (2017). Environment 2 Perspective [Unreal Engine 4 Rendering].

< Figure 4l> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

< Figure 4m> Vallo, L. (2017). Environment 1 Perspective [Unreal Engine 4 Rendering].

<Figure 5.3.1.1> Vallo, L. (2017). Normalized Heart Rate Environment 1 [Excel Graph].

Tables

APPENDIX

APPENDIX I
Experimental Results Survey

Experimental Results

Evaluating Stress Recovery by Exposure to Nature

Participant #: _______

Environment: _______

Demographics:

1. Age: What is your age? ________

2. Gender: M/F?________

3. Education: Are you currently enrolled as a university student? ________
   a. Yes - what year are you in:____________
   b. No

4. Education: If no, please specify your highest level of education? ________
   a. High school diploma
   b. Some University
   c. Undergraduate degree
   d. Graduate / professional degree
   e. None of the above

5. Ethnicity origin (or race): Please specify your ethnicity: ________
   a. Caucasian
   b. Hispanic or Latino
   c. Black or African American
   d. Native American or Indian
   e. Asian / pacific islander
   f. Other
6. How often do you experience anxiety?
   a. Never
   b. Almost never
   c. Sometimes
   d. Fairly often
   e. Often
7. In the last month, how often have you become upset because of something that happened unexpectedly?
   a. Never
   b. Almost never
   c. Sometimes
   d. Fairly often
   e. Often
8. In the past month, how often have you felt unable to control the important things in your life?
   a. Never
   b. Almost never
   c. Sometimes
   d. Fairly often
   e. Often

9. In the past month, how often have you felt nervous and stressed?
    a. Never,
    b. Almost never
    c. Sometimes
    d. Fairly often
    e. Often

10. How often do you watch scary movies?
    a. Never
    b. Almost never
    c. Sometimes
    d. Fairly often
    e. Often

11. How well do you deal with the sight of blood?
    a. Poorly (fainting or other physiological responses)
    b. Somewhat poor (no fainting, but very uncomfortable)
    c. Unsure
    d. Blood doesn't bother me very much
    e. Blood doesn't bother me at all

12. Empathy: How much do other's emotions influence your own?
    a. None
    b. Somewhat
    c. Quite a bit
    d. Strongly

13. Please state your perceived stress level scale 1-5:
    a. 1. Not stressed
    b. 2. Somewhat stressed
    c. 3. Neutral
    d. 4. Stressed
    e. 5. Very stressed

14. Have you ever experienced virtual reality? Y/N

15. What do you do to relieve stress?
    a. Exercise
    b. Drink
    c. Spend time in nature
    d. Eat
    e. Recreational drug
    f. Spend time with friends
    g. Other______________

16. How likely are you to use a walk to relieve stress?
    a. No
    b. Not likely
    c. Somewhat likely
    d. Likely
    e. Very likely

17. How likely are you to use a walk to connect to nature?
    a. No
    b. Not likely
    c. Somewhat likely
    d. Likely
    e. Very likely

18. Have you consumed caffeine today? Y/N ______

19. Have you consumed alcohol in the past 24 hours? Y/N ______

20. Have you taken a recreational drug in the past 24 hours? Y/N_____

***Proctor will fill out the rest of this worksheet based on your answers. You will now be fitted with the oculus rift and infinity systems.**

6. Stress level rating #2 Post-video stress level: ______________

7. Stress level rating #3: Post-VR stress level: _______________

APPENDIX II
Testing Procedure

Testing Procedures Steps

Evaluating stress recovery by exposure to nature in virtual environments

Location: English Counseling Services conference room second floor

Time: TBD

Date: TBD (must be during times where counseling services are not offered)

Proctors:

Items required for test:

Technology

Computer: (1) Gaming Computer (1) Keyboard

Oculus: (2) Rift DK2, (2) Rift sensors, (2) HDMI cords, (2) Oculus cords *name?

HTC Vive: ? have not seen this device and am unsure if it is compatible with UE4

Infinity Systems: ?

Video: https://www.youtube.com/watch?v=xxw5gl1Z2Yk *first 5 minutes*, (3)

Paperwork

Introduction: debriefing statement, consent form, experimental results paper.

Testing Procedures

***Note* (**if multiple tests are conducted simultaneously) students in the same room should be shown the same environment.

Room Preparation:

1. **Technology setup:** Set up computer, monitors, and oculus equipment
2. **Biofeedback setup:** setup watch, infinity system, and other devices used for biofeedback collection.
3. **Volume check:** check speakers / headphones to ensure they are working properly.

Test Preparation:

4. Layout oculus equipment and biofeedback equipment at seat for participant. Place the experimental results paper on desk (follow participant # chronologically). Each experimental results paper will be pre-numbered determining the participant #. The environment # will also be specified on this paper. Open the oculus file for the specified environment.

a. *NOTE* in the case of testing multiple students, it is imperative to keep track of testing form during the procedures as other data will be filled in by the proctor.

Introduction

1. **Consent form:** Have students read and sign consent form. Answer any questions that may arise.
2. **Debriefing Statement:** Read students the debriefing statement. Once again, please answer any questions that come up during this time. At this time, please collect a valid form of identification from participant in case participant damages equipment.
3. **Experimental Results:** Hand out demographics survey. Allow students to fill out demographics survey on their own (this data will include initial perceived stress level). Once finished, collect the experimental results paper.
4. **Equipment fitting:** *Oculus headset, joystick, headphones, infinity system, empatica.*
    a. **Oculus Rift:** Comfortably fit and adjust headset for participant
    b. **Joystick:** Hand participant joystick and ask if there are any questions.
    c. **Headphones or speaker:** if headphones, place headphones over oculus headset
    d. **Infinity Systems:** place infinity system on participant's finger *should be placed on non-dominant hand
    e. **Empatica:** fit watch to student.

Stress Induction

5. **Video: *It didn't Have to Happen:*** Press play on youtube video. Video should play in the oculus googles. Participants should have *headphone or speaker* access to sound
6. **Experimental Results (Perceived Stress Rating #2):** Once the first 5 minutes of the video has played, stop video and ask participants to report their perceived level of stress. This should be on a scale of 1-10 *if multiple tests are being run simultaneously, it may not be best for students to audibly record stress levels. Other suggestions??

Stress Reduction

7. **Virtual Environments:** play the virtual environment # corresponding to the Experimental results sheet. Participants will be immersed in the virtual environment for 10 minutes
8. **Experimental Results (Perceived Stress Rating #3):** see step 6- collect final perceived stress rating.

Collect Equipment

9. Collect equipment and return identification card.

APPENDIX III
Informed Consent Form

KANSAS STATE UNIVERSITY
INFORMED CONSENT FORM

Evaluating Stress Recovery by Exposure to Nature

APPROVAL DATE OF PROJECT: **EXPIRATION DATE OF PROJECT:**

PRINCIPAL INVESTIGATOR:
Dr. Brent Chamberlain (Primary Investigator and Contact)
Assistant Professor
Landscape Architecture and Regional & Community Planning
Kansas State University

CO-INVESTIGATORS:
Laura Vallo, Graduate Student, Landscape Architecture
Brandon Irwin, Assistant Professor, Department of Kinesiology, Kansas State University
Jeffery Skibins, Assistant Professor, Department of Horticulture, Kansas State University
Bill Hsu, Associate Professor, Department of Computer Science, Kansas State University
Heath Yates, Ph.D. Candidate, Department of Computer Science, Kansas State University

IRB CHAIR CONTACT INFORMATION:
Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506

Cheryl Doerr, Associate Vice President for Research Compliance, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224

PURPOSE OF THIS RESEARCH:
The purpose of this research is to further understand how varying degrees of exposure to nature influences the amount of time it takes to recover from induced stress. By using a virtual environment, we can manipulate the same environment with different variables. This allows complete control over the testing environment as well as analyzing similarities between testing environments and results. Understanding stress recovery response can influence high stress places (such as the office or school) to have a positive impact on stress recovery and reducing the negative side effects associated with a stressful life.

PROCEEDURES OR METHODS TO BE USED:
Following the signing of this consent form, you will be debriefed on the equipment to be used during the testing procedure. First you will be given a watch to wear that will track various biophysical indicators. Some participants (chosen at random or participant self-selected) will also be connected to an EEG, an electroencephalogram. This device measures brain activity and will help us get a better idea on the level of stress experienced. Next you will be asked to take a brief demographics survey and rate your perceived stress level upon entering the test. Following the survey you will be asked to watch 5 minutes of the video, *It Didn't have to Happen.* The video is purposefully used and has been proven to induce stress. When the video has concluded, you will be asked to once again rate your perceived stress levels. You will then be handed the virtual reality equipment which you should be familiar from the debriefing segment. Once the goggles are on, you will use the controller to walk through the virtual environment. Upon completion of the virtual reality environment and returning the equipment, you will be asked once again to rate your perceived levels of stress.

LENGTH OF STUDY: The study will require an expected 30 minutes of your time. However, if you are using the EEG, the total time burden will be around 60 minutes.

RISKS OR DISCOMFORTS ANTICIPATED:
Due to the nature of the testing environment, this should be a relatively safe testing procedure. Using virtual reality significantly reduces risks associated with reality. However, if you have been diagnosed with vasovagal or have previously fainted at the sight of blood, you will be asked to continue at your own risk or withdraw participation as the content of the video may not be favorable. If extreme discomfort is felt at any time during testing, you are free to withdraw. If using the EEG, there is a very small chance of skin irritation or breaking of the skin. However, this is highly unlikely.

BENEFITS ANTICIPATED:
There will be no compensation for participating in this test. However, the information you are contributing is very valuable and you can receive a follow-up if you wish.

EXTENT OF CONFIDENTIALITY:
All data will remain anonymous. The data that is collected will be stored on collaborators computers during the study and for at least 5 years following.

IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS: No compensation or medical treatment will be provided due in the instance of injury.

TERMS OF PARTICIPATION: I understand this project is research, and that my participation is completely voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

I will be given a copy of the signed and dated consent.

WARNING: IF YOU HAVE BEEN DIAGNOSED WITH VASOVAGIL SYNCOPE OR HAVE PREVIOUSLY FAINTED OR BECOME ILL AT THE SIGHT OF BLOOD, YOU MAY WANT TO WITHDRAW YOUR PARTICIPATION.

Participants Name: ___________________________

Participants Signature: _________________________________ Date:________________

APPENDIX IV
Briefing Statement

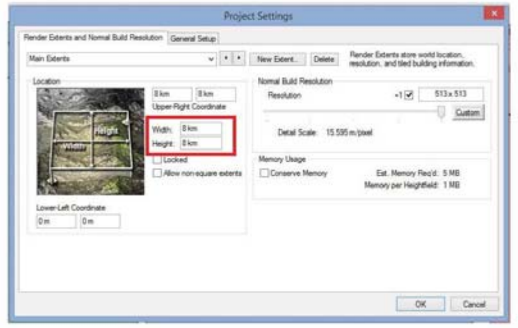
Briefing Statement

Thank you for participating in this research. This study examines how varying degrees of nature in virtual reality environments influence stress recovery. Your role in this research is to produce data based on your behavioral and biophysical response to the given circumstances. The devices that will be using will measure your responses to the environments you will encounter. These measurement will include heart rate variance and electrodermal activity. These variables have been identified by medical research as means of quantifying levels of stress. You will be using this equipment during the initial video and while using the gaming system, Oculus Rift. The video you are about to see may produce some stress. If you have fainted or experienced extreme stress due to the sight of blood or seeing others in pain, you can opt out now. If you wish to proceed, you will watch the video, report your perceived stress levels and then begin the virtual reality portion of this study. You will be in a virtual environment for ten minutes. During these 10 minutes you will be free to roam the natural setting presented. During this time stress recovery levels will be analyzed. The entire process should take less than a half hour .Thank you for volunteering your time, your feedback is very valuable.

APPENDIX V
World Machine | Unreal Engine Terrain Tutorial

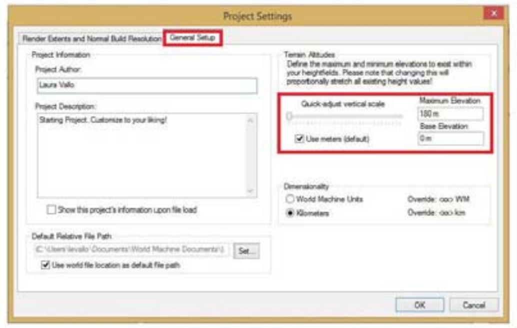
World Machine- Terrain

1. 1. To format project World Commands>**Project World Parameters**



2. 1. In the Projects Settings window, change parameters as desired

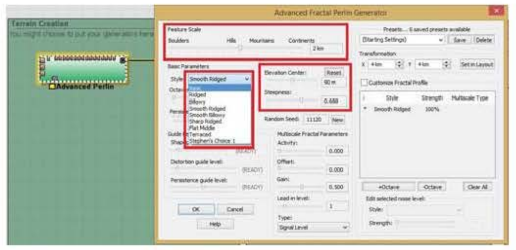
*note: depending on computer you may need to change resolution



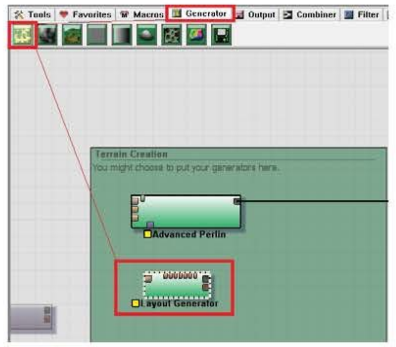
3. 1. In the **General Settings** tab, you can adjust the minimum and maximum altitude

1 https://www.youtube.com/watch?v=5dkP-XcLSG4

World Machine- Terrain

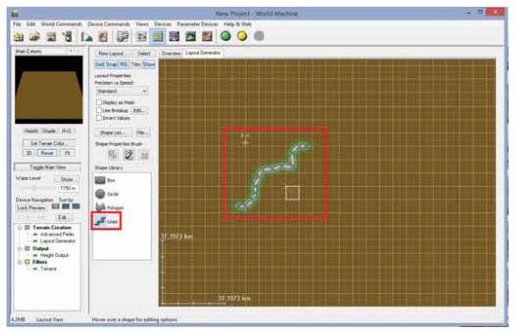


4. 1. Double click **Advanced Perlin**
2. Change parameters as seen in image to desired terrain type

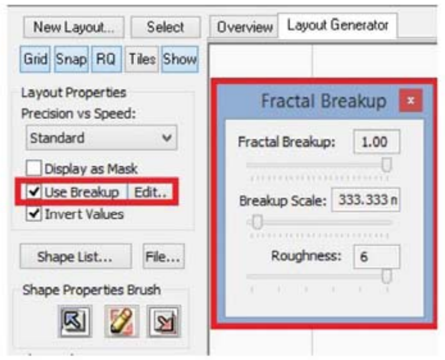


5. 1. Drag and drop **Layout Generator** from the tab shown in the image

2. Double click the tab you just created



6. 1. Use lines to draw and customize terrain

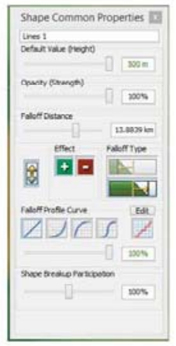


7. 1. Check **Use Breakup**

2. Edit as desired

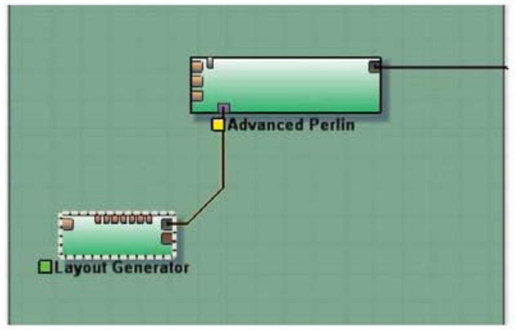
8. 1. Hover over line and right click

2. **Edit**

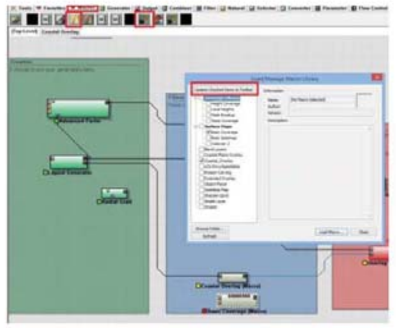


9. 1. The editor allows you to edit the terrain as you wish.

1 https://www.youtube.com/watch?v=5dkP-XcLSG4



10. 1. Connect the Layout Generator to the Advanced Perlin to create more realism along the terrain

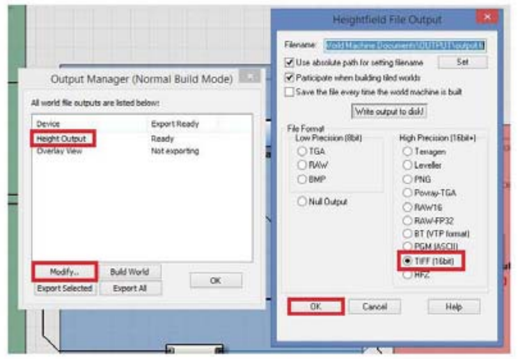


11. 1. Click on the tab **Macros** or type **M**

2. Click the folder icon

3. Check desired macros in menu and click add to tool bar

4. Drag ocean overlay and bitmap to the graph



12. 1. File > **Export**

2. Highlight **Height Output** and select **Modify**

3. Set file path and select TIFF or desired file type

4. Select **Write output to disk** then click okay

5. Export

World Machine- Terrain

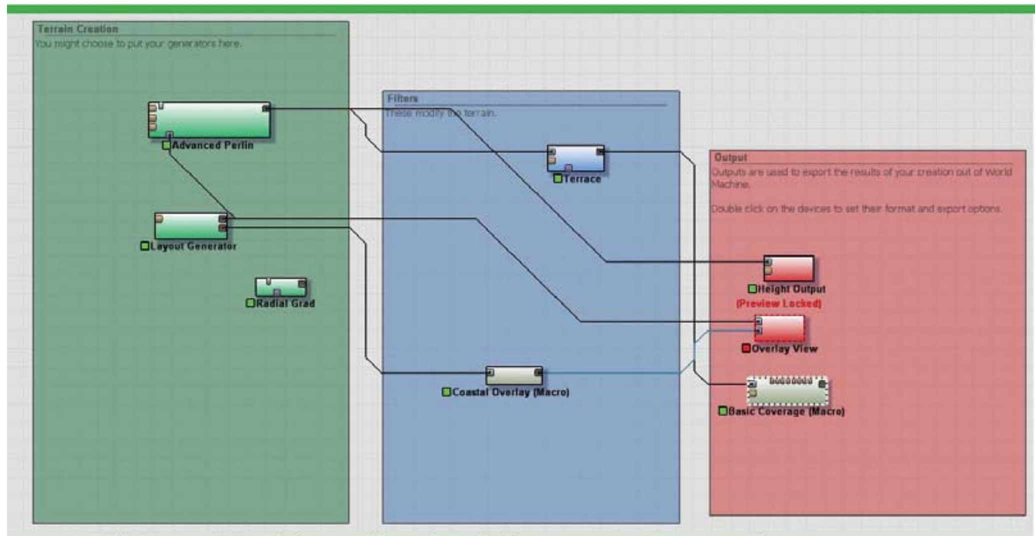
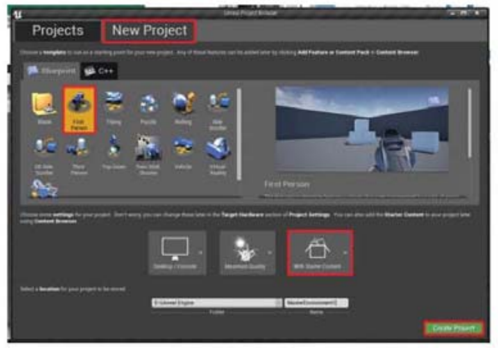


Table X: Final Graph for world machine before exporting in to unreal engine

UNREAL ENGINE 4



1. 1. Open Unreal Engine

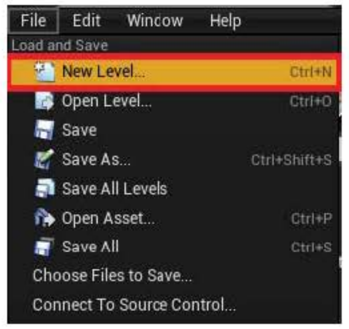
2. Create New Project

3. Select **First Person** and make sure to include starter content

4. Name Project and Create

https://www.youtube.com/watch?v=5dkP-XcLSG4

Unreal Engine 4- Terrain



2.

1. Open a new level

2. Click the first option, **Default**

3. Delete the floor in the level

2

APPENDIX VI

Unreal Engine 4 Road Tutorial

Unreal Engine- Roads

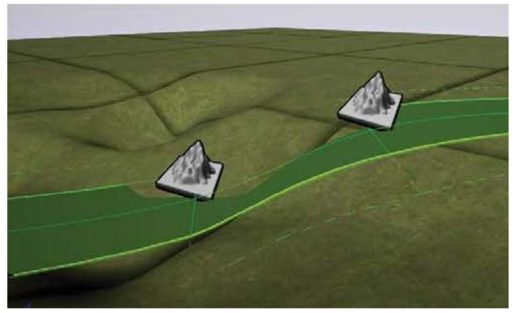
1.

1. Under the **mode** tab, click landscape
2. **Manage**
3. Landscape Editor > **Edit Splines**

2.

1. Ctrl + Left Click to set first point of spline

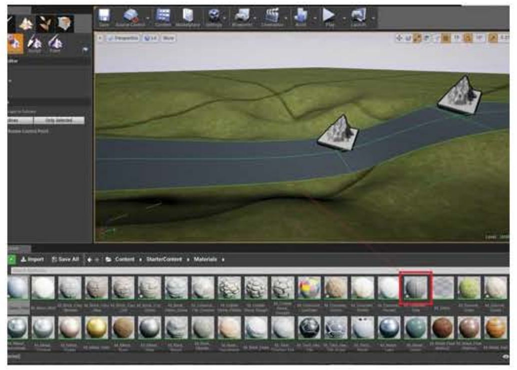
*The start point will look like the landscape mode icon



3.

1. Ctrl + Left Click a second point to continue your road

*The **Landscape Spline Tool** smooths existing terrain to allow for features like roads

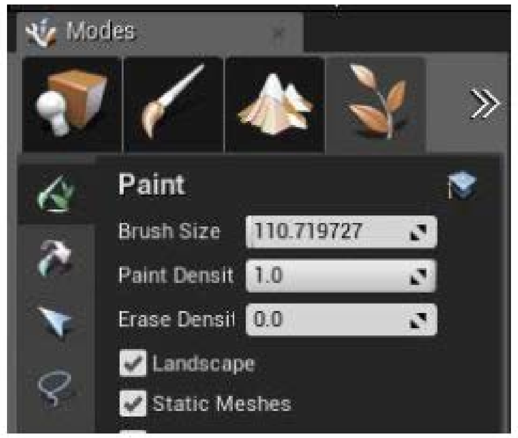


4.

1. Drag and drop material or mesh from the content browser to fill the landscape spline

APPENDIX VII

Unreal Engine 4 Foliage Tutorial

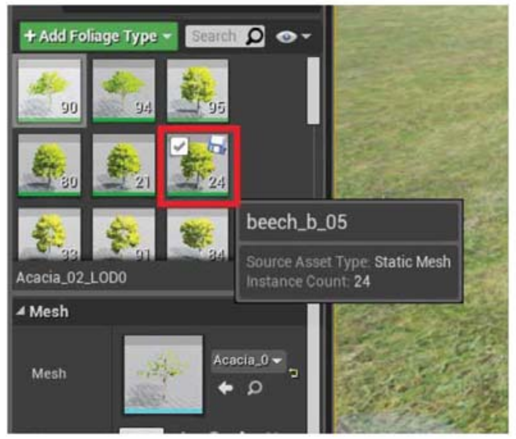


1. mode>foliage

2. 1. From the content editor, select the desired meshes for foliage type
2. Drag and drop the meshes

3. 1. Alter individual properties of the mesh by selecting it and choosing the desired settings listed below

Unreal Engine- Foliage



4. 1. modify the desired selection by checking which foliage types you would like to include in your paint brush

5. Paint landscape using the specified brush. As seen in this image, the density setting can be especially frustrating. There are multiple density settings that will need to be altered

6. Continue painting landscape

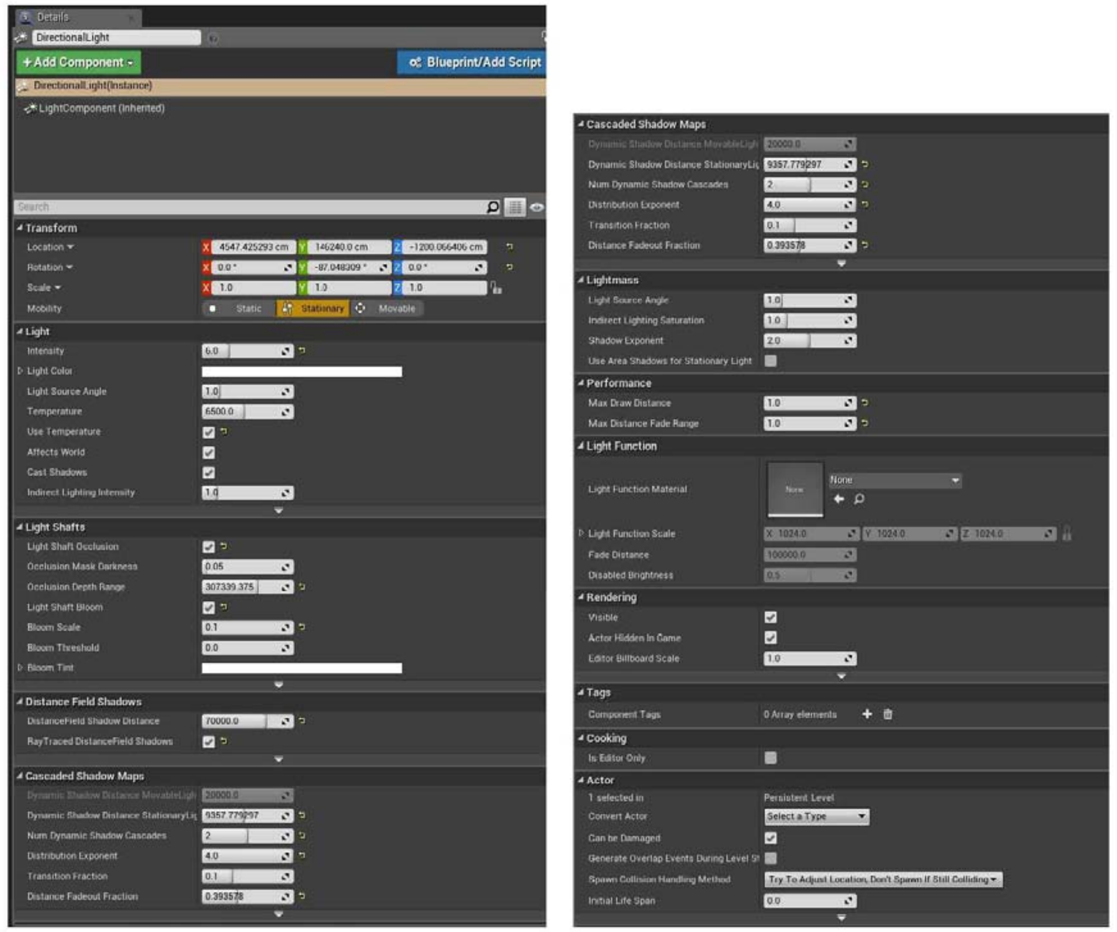
*note: there are many other options available. this was the method used in this project. It was very time consuming and It is suggested that other options are explored.

3

APPENDIX VIII
Lighting Settings

APPENDIX IX
Directional Light Settings

Directional Light Settings

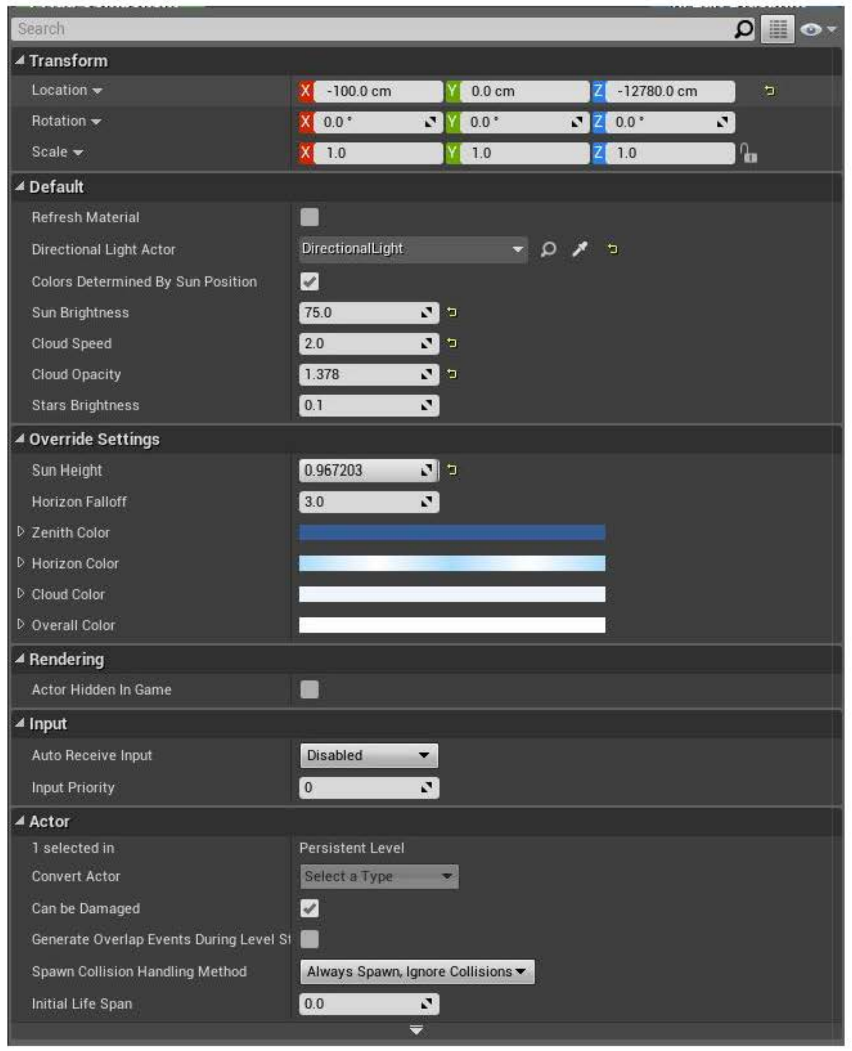


APPENDIX X
Skylight Settings

Skylight Settings

APPENDIX XI
Skysphere Settings

Skysphere Settings



APPENDIX XII
Atmospheric Height Fog

Atmospheric Height Fog

APPENDIX XIII
Exponential Height Fog

Exponential Height Fog