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Master's Thesis
Academic Year 2022

Transcendental Avatar: Experiencing Bioresponsive Avatar of the Self for Improved Cognition

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2022

Transcendental Avatar: Experiencing Bioresponsive Avatar of the Self for Improved Cognition

Category: Design

Summary

Biofeedback is a well-known therapy method where visual and audio feedback of one's own physiology are used for them to reflect, recognize, and be aware of them to improve their cognitive and emotional state. Yet, there has been very little works on how this can be properly leveraged in virtual reality (VR). In Transcendental Avatar, we propose virtual reality avatars of the self that are bioresponsive; it reacts to a user's own physiological state, namely their heart rate and electrodermal activity. The user can perceive the change in their self avatar when presented with emotional stimulus and experience the change in their avatar's appearance and presence. This study investigated whether and how the immersion environment with the avatar generated by visual features reacts to the individual personification of biofeedback can help relieve or reduce stress levels and self-reported anxiety symptoms.

Keywords:

immersive experience, avatar, biofeedback, virtual reality, anxiety, stress, relaxation

Keio University Graduate School of Media Design

Kinga Skierś

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Chapter 1
Introduction

1.1. Overview

Mental health affects our whole lives. When we are mentally healthy and stress-free, it allows us to fully participate in social life, realize our needs, attend social events, work more productively and manage various situations. However, nowadays, people live under burdensome stress, which negatively affects daily functioning, and in some cases, prevents day-to-day basis. For instance, according to the scientific brief publicized by the World Health Organization (WHO)[1] published on March 2, 2022, global anxiety and depression prevalence increased by 25% during the first year of the COVID-19 pandemic, in the same time over 264 million people of all ages suffer from depression and anxiety disorders, making them the most common mental illnesses in the world. An explanation for the increasing mental health condition lies in the unprecedented stress induced by social isolation and restrictions on people's capacity to work or visit friends or relatives and participate in their communities.

In addition, loneliness, fear of infection, misery, death for oneself or an adored one, grief following a loss, and financial and economic worries are all cited as contributing factors to evolving anxiety and depression during COVID-19.

A comprehensive review of the evidence concerning COVID-19's [1] impact on mental health reveals that youthful individuals have been adversely affected. For example, there has been a growth in suicide attempts and self-harming behavior. By the end of 2021, the condition had slightly enhanced, but today excessively, many people remain incapable of receiving the maintenance and support they

1 https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide

need.

In modern psychology, the characteristics of the stress reaction can be defined at the cognitive, emotional, behavioral, and motivational levels. The body reacts to various experiences and events that disturb its balance and overburdens or exceed the person's ability to cope effectively with daily life. Too long, repetitive exposure to stress causes increased cortisol levels (a steroid hormone that affects blood glucose levels - in response to stress, it increases its level). At the same time, the levels of serotonin and dopamine (neurotransmitters called happiness hormones, responsible for the well-being, optimistic attitude, and willingness to act.), i.e., neurotransmitters, the deficiency of which can cause disorders in the functioning of the body, decline.

Various relaxation techniques [2] were created to better cope with increasing pressure. A feared individual can use relaxation techniques to manage their emotional tension and clear their minds. Relaxation does not replace psychotherapy, but it does assist in behavioral therapy. It is intended to relieve tension in the mind, muscles, and mind to achieve peace. In addition, it helps better understand the body's reactions and control them. Relaxation techniques reduce stress and significantly control reactions; for instance, breathing exercises, meditation and mindfulness meditation, yoga, rhythmic movements, visualizations, Jacobson's progressive muscle relaxation technique [3], and Shultz's autogenic training [4]. Various techniques could be improved by combining with a Virtual Reality system. Virtual Reality (VR) has become a beneficial tool in depression, phobia, or anxiety treatment in the past few years.

According to recent studies [5], the simulation in Virtual Reality helps patients learn how to cope with their symptoms better and decreases the intensity of the nervous tension. In such a dynamic world, society is increasingly demanding; people are exposed daily to tense circumstances that negatively affect overall mental health, leading to severe disorders and health trouble. Therefore, significantly behind the global COVID-19 pandemic, it is undoubtedly essential to concoct unique technological approaches that will allow us to de-stress and regain peace of mind. Although, as mentioned earlier, there are many techniques to assist relaxation and lower anxiety or stress, we as a society continue looking for new solutions on an extensive scale worldwide. Hence, predicting world events or tragedies such

as wars, pandemics, and natural disasters is unattainable. However, as a society, we should be prepared for any eventuality. Mental well-being, also known as well-being or mental balance, is fundamental to proper human functioning. It is correlated to mood and perceived emotions and is also inextricably linked to physical health and overall wellness.

1.2. Contributions

This research aims to establish and evaluate a new Virtual Reality system for relaxation experiences. Furthermore, explore new possibilities for using a VR system for mindfulness, and analyze VR technology solutions currently being explored worldwide. Finally, this study demonstrates that Virtual Reality can be used in diverse forms.

Transcendental Avatar is a VR technique that portrays the user's avatar as a reflection of their cognitive and emotional state. Our self-supporting system aims to assist with relaxation and calming techniques. Transcendental Avatar was developed after analyzing currently available research on blending Virtual Reality with relaxation techniques and self-awareness. We will present our findings in the "Literature Review" chapter. Furthermore, considering the growing worldwide situation with mental health problems, we decided to undertake our research to create new relaxation and calming down techniques using Virtual Reality technology. Stress and anxiety are global problems that require more technology systems and solutions to cope with them.

That is why we want to provide a VR system to support self-relaxation and relaxation techniques by showing the Transcendental Avatar, the personification of users based on physiological signals. This study has the prospect of presenting a method that can assist people in self-relaxation and easing stress.

- **Create a Virtual Reality system 'Transcendental Avatar' to determine the use of this method as a supporting tool to ease anxiety and stress levels.**
- **Specify to which extent the use of bioresponsive self-avatar can influence the relaxation process.**

1.3. Motivation

Mental health is essential because of the consequences that can bring potential cognitive breakdown. Although the progress of civilization has made us live longer and more comfortably, it also directs to general stress, neurotic situations, and anxiety. The vast number of stressors surrounding people makes it impossible to escape them. Periodically it can be mobilizing, but when the state of tension persists for a long time, it damages our health. The initial phase or prolonged stress can decrease quality of life, leading to much more severe health consequences or a suicide attempt. It is also worth mentioning that over 700,000 people commit suicide every year (meaning one person every 40 seconds) [6], with even more having suicide attempts or self-harm. Many of these cases result from gradually developing stress leading to major depressive disorder. In addition, numerous impulsive moments during a crisis or emergency derive from personal troubles, anxiety, and loneliness. We live in such a fast-paced and demanding world that requires us to take care of mental health, find a form of relaxation that suits personal needs, and look for new solutions.

1.4. Thesis Structure

This thesis consists of 6 chapters, as follows:

- **Chapter 1: Introduction** This chapter will mainly introduce and summarize the motivation and contribution for conducting this research. Then, a brief explanation of Virtual Reality, anxiety, stress, and the significance of relaxation. It will gives the structure of the whole thesis.
- **Chapter 2: Related Works and Literature Review** The second chapter overviews related works and exemplify the researchers and theory of anxiety, stress, anxiety disorders, relaxation techniques, Virtual Reality, and Virtual Reality Therapy. Existing tools and researchers integrate Virtual Reality, anxiety/stress/physiological sensors, and emotions.
- **Chapter 3: Concept Design** Elaborate on the concept and design of the proposed solution. Includes the survey, previous user study, hypothesis, and

explanation of Transcendental Avatar's name and how the prototype was developed.

- **Chapter 4: Proof of Concept** We will foremost portray the design and procedure of our system. Then, this chapter is correlated with prototyping interactions and exemplifies the empirical setup. We also cover the experimentation and user study, the outcome, and the discussion of the results. We will present our results and findings based on the experience and feedback given by participants.

- **Chapter 5: Conclusion** Finally, we will discuss what those results mean for self-support relaxation and how they can be used in future works. Objectives for this research's future academic potential development will also be outlined.

Chapter 2
Literature Review

This chapter will introduce previous related works from different academic studies. To better understand the context and scope of this research, we need to analyze and present some fundamental concepts and their development in the research field of: Virtual Reality, mental health, physiological signals, emotions, meditation, and mindfulness. Each chapter will shortly overview the selected research and technology examples, which are essential for the design process of the presented system.

2.1. Mental Health

2.1.1 Stress

The term stress comes from physics and refers to myriad stresses, pressures, or forces acting on a system. It was introduced to the medical lexicon by pioneering Hungarian-Canadian endocrinologist Hans Hugon Selye (1907–1982) in 1926 [7] to describe the "nonspecific response of the body to any demand." However, the term became widespread in the 1970s. Stress is the body's reaction to various experiences and events. It is something that accompanies us almost every day. Moderate stress expands the capability to cope with the adaptive demands of the environment, thus enabling psychological development.

Many researchers of the phenomenon define it as an essential factor of development. However, too severe stress (overextending the individual's adaptive capacity) or too prolonged brings grave consequences, affecting cognitive and physical health. In other words, stress is feeling overwhelmed or incapable of dealing with mental or emotional pressure. Hans Selye, in 1946, first conceived General Adaptation Syndrome (GAS) [8, 9] to distinguish and describe how the body responds

to any stress, whether positive or negative. He characterized three phases during a stress reaction by observing the GAS phenomenon—a distinctive cluster of physiological modifications that the body experiences indicate each stage.

- **Alarm Reaction Stage** The first stage is when the body sends a distress signal to the brain and the heart rate increase. In response, the brain transmits a notification to the adrenal gland to unleash cortisol (a stress hormone) and boost glucocorticoids and adrenaline.

- **Resistance Stage** The stage that happens after the 'Alarm Reaction Stage.' The body utilizes the parasympathetic nervous system to neutralize changes from the first stage. Even though this is a moment of repair, the body remains in a state of high alert. The body will return to its natural order if the stress can be controlled and the situation is not critical. However, if the stress lasts a more extended time, the body may adapt to the new situation and learn to live with a high-stress level. The body begins accumulating cortisol, and blood pressure will continually elevate. If this situation continues too long, it can lead to the last phase. Some signs of the resistance stage include frustration and problems with concentration.

- **Exhaustion Stage** The final phase results from exposure to prolonged, harmful stress. It can negatively affect mental health, physical health, and emotions and lead to a point where the body is shattered and cannot continue to react to stress levels. Some of the symptoms of the Exhaustion Stage are burnout, depression, mood swings, anxiety, and a significant decrease in tolerance to stressful situations.

Long-term exposure to stress can lead to chronic stress, i.e., stress experienced too long, and many diseases. As a result, Psychological indicators (E.g., irritability, apathy, hostility, the feeling of loneliness, and disturbing self-esteem). In addition, physiological indicators (E.g., increased sweating, palpitations, tightness in the throat, gastric problems) and Behavioral indicators (E.g., changes in behavior, nervous tics, sleep disorders, uncontrolled emotions, conflicts, impulsiveness, susceptibility to addictions) symptoms can develop.

The most common symptoms of chronic stress include stomach ulcers, hypertension, heart disease, asthma, sleep disorders, eating disorders (anorexia, bulimia),

skin disorders such as hives, eczema, herpes, or sexual desire disorders in men, and menstrual disorders in women. Moreover, in expansion, prolonged stress conditions can conduct to neurotic responses, such as anxiety or depression. Everyone feels stress differently, and diverse characteristics activate it.

The Holmes and Rage Stress Scale [10, 11] lists the 43 most stressful life events that can lead to the diseases mentioned above. In 1967, two psychiatrists, Thomas Holmes and Richard Rahe conducted medical research on more than 5,000 medical patients to determine whether stressful situations could cause illness. As a result, some of the most stressful factors and events include the death of a spouse, divorce, incarceration, death of a close family member, co-morbidities, marriage, work-related problems, pregnancy for minor patients, parental death, unplanned pregnancy, marriage, parental divorce, acquiring a visible deformity. Nowadays, one of the most significant stressors is the job. Stress at work occurs when a person at work, whether an employee or employer, experiences significant psychological affliction due to working conditions and demands when, at any given time, these conditions exceed their capabilities. The employee's inability to meet the employer's expectations creates stress and frustration. This concern can occur at any time but is particularly likely to escalate when an employee has little control over their work or receives no support from other employees or supervisors.

For work-related stressors, there are few categories of stressogenic factors nature of work [12]:(monotonousness in performing activities), workload (working under time pressure, too numerous or too few tasks to perform), hours of work (strict adherence to hours and time off work, working beyond hourly standards), career development (lack of secure employment or lack of opportunity for advancement, more competence than assigned), role in the organization (conflict of roles at work, unclearly defined role), interpersonal relationships (rude and abusive supervisor, lack of camaraderie at work), organizational culture (drought or poor communication in the company, lack of transparency), and work (lack of balance between private life and work).

As mentioned earlier, prolonged stress states can lead to significant and critical health problems. One particular symptom of prolonged stress when it comes to work is job burnout. German-born American psychiatrist Herbert Freudenberg first described it but was later popularized by Christine Maslach [13] (born Jan-

uary 21, 1946), an American social psychologist and professor in the psychology department at the University of California. She developed a measurement tool that allowed her to conduct thorough research on burnout. At first, it was thought to primarily affect direct service professions, such as nurses, teachers, doctors, and social workers. However, according to Maslach, the high demands of a job can lead to symptoms of severe stress after some time. Maslach described it into three categories [14]:

Emotional exhaustion For example, lowered mood, anxiety, depression, disappointment, and somatic complaints.

Depersonalization Indifference and sometimes even hostility towards the other person (in this case, the mentee), physical avoidance of contact.

Lack of achievement at work Pessimism, lack of desire to work, and low self-esteem in one's professional capabilities.

Professional burnout is observed mainly among young people with short work experience. Therefore, the above examples refer to any profession.

The incoming psychosocial stimulus is thus related to the individual's value system, habits, aspirations, and abilities. On this basis, an assessment is formulated of how threatening the situation is. The emotional level is closely coupled with the cognitive level. Recognition of the situation as threatening is accompanied by general emotional arousal, plus such emotions as anger, irritation, and impatience also appear as the feeling of guilt or shame. Therefore, the problem associated with stress and the processes of coping with it and its consequences is a constantly relevant and current topic for discussion. From presently available research on stress, it can be concluded that self-relaxation techniques can reduce the intensity of stress and mitigate its negative consequences. Self-relaxation methods and others will be explained in more detail in chapters: Relaxation Techniques and Meditation and Mindfulness.

2.1.2 Anxiety

As discussed earlier, stress can be caused by various situations or life events. On the other hand, feeling anxious is the human body's response to feeling under an unknown threat or being apprehended about unexpected forthcoming possibilities. Anxiety [15], often equated with fright, is usually induced by lengthened tension.

Feelings of anxiety can interfere with daily functioning and are hard to control. The ability to deal effectively is individually conditioned. Personality traits, life experience, support from the environment, worldview, and way of reflection are paramount factors influencing it.

Common anxiety symptoms [16] have been defined as: feeling nervous, stressed, having a sense of being in danger or panic, increased heart rate, breathing rapidly, muscle tension, increased arterial blood pressure, tachycardia, trembling, sweating, feeling weak, and trouble concentrating. Overly intense and irrational feelings of anxiety that impact quality of life and the ability to function in society (when it influences activity, work, school, and interpersonal affinities) can evolve into an anxiety disorder. Anxiety disorder affects nearly 30% of adults at some point in their lives, making it the most common mental illness in the world. Specimens of anxiety disorders [17] include:

- **Generalized anxiety disorder (GAD)**
  Generalized anxiety disorder [18] is a mental and behavioral disorder. As in the above-described anxiety disorder, there are uncontrolled and irrational attacks of fear about events that have not happened, exaggerated worry and tension. The worrying often makes it very difficult to function in society. People with GAD often worry about health, finances, family, friends, work, or school. They worry about situations that "have a right to happen in the future" but do not have to happen.

  Anxiety symptoms must last at least six months to be classified as Generalized anxiety disorder. Individuals who have this disorder often also suffer from Major Depressive Disorder. GAD symptoms can also appear as side effects of medications or addictive substances. It can be caused by prolonged conflict and stressful situations in the family, work, or another environment. Symptoms of GAD are very similar to other symptoms in the anxiety disorder family, including Nausea, urinating, poor concentration, inability to relax, sleep problems or insomnia, and a lump in the throat. Generalized anxiety disorder usually becomes active in childhood or the teenage years, but it can also occur in adults. Treatment for GAD includes medication, cognitive behavioral therapy or physiotherapy [19], relaxation techniques, therapy, changing lifestyle to reduce stress levels, and avoiding stimulating

substances.

- **Social anxiety disorder (also known as a social phobia)**
  Social phobia [20] is characterized by symptoms that are basic to all anxiety disorders and include anxiety that is inadequate to the threat, rapid heartbeat, sweating palms, hand tremors, and dizziness. In the case of social phobia, these symptoms appear and intensify in situations where the individual is exposed to interpersonal contact, primarily towards strangers. Individuals with this problem may not be able to perform in public or take jobs that rely on interpersonal communication. There are two types of social phobia, generalized and isolated. In the case of the former, symptoms appear and increase in all interpersonal interactions. It can also lead to extreme isolation and withdrawal from public life. In comparison, the second form is much milder and evokes only mental discomfort and some anxiety symptoms. Most often, the first symptoms of social phobia appear during childhood and adolescence.

- **Specific different phobias**
  The phobias referred to in this section can be very varied. However, they are often accompanied by the typical irrational Fear of Anxiety disorders, which may involve situations, animals, places, or objects. Phobias [21] include Aquaphobia: fear of water, Acrophobia: fear of heights, Erythrophobia: fear of blushing, Hypochondria: fear of becoming ill, and Zoophobia: fear of animals. People can develop a phobia about, literally, anything. Sometimes phobias emerge occasionally as society changes. For example, one conceivable phobia is Nomophobia, the fear of being without a computer or phone.

- **Panic disorder**
  When panic attacks, chaperone anxiety appears unaware bouts of nervousness and a sense of tremendous, overwhelming tension. These attacks can distinguish sudden waves of fear, losing control, and overwhelming discomfort even when there is no apparent danger. The panic attack state may last from a few minutes to even two hours. The most common symptoms of panic attacks are intense, rapid breathing, chest pain, uncontrolled shal-

low breathing, trembling all over the body, shortness of breath, feeling hot, sweating or passing out, weakness, stomach pain, and nausea. Some of the symptoms may be mistaken for stroke or heart attack symptoms. Panic attacks [22] occur in approximately 9% of the population. Panic disorder often begins during the teenage years or early adulthood; women are much more susceptible to developing the panic disorder than men. One way to deal with panic attacks is through breathing and sedation techniques. It is equally essential to identify the thoughts that this state is not life-threatening and the emotions tormenting during a panic attack; soon will reduce emotional tension, reducing pressure on the whole body.

It is worth noting that not everyone who experiences panic attacks will also develop panic disorder. To treat panic attacks, the most common treatment is Cognitive behavioral therapy (CBT), a research-supported type of psychotherapy. CBT [23] teaches you to think and react differently to better prepare for, anticipate, or respond to an attack. Exposure Therapy is prevalent in CBT and focuses on encountering a person with the fear and speculations associated with the advent of panic attacks. Often Exposure Therapy also merges aspects of relaxation exercises. The pharmacological medications most commonly used are serotonin reuptake inhibitors (SSRIs) and serotonin-norepinephrine reuptake inhibitors (SNRIs), Beta-blockers, and Anti-anxiety drugs (for example, benzodiazepines).

- **Other specified anxiety disorders and unspecified anxiety disorder** This is an indeterminate anxiety disorder that does not fit into typical patterns or is under diagnostic criteria but could potentially be interpreted in the future.

2.1.3 Relaxation Techniques

Relaxation techniques are a crucial element in reducing stress and improving the body's nervous system. The relaxation response is the opposite state of anxiety. Relaxation is when the body is relaxed, and stress reactions are stopped. It is the ability to relax your body consciously.

Jacobson's Progressive Muscle Relaxation (PMR) [24, 25], this technique was invented by an American psychologist Edmund Jackson (April 22, 1888 - January 7, 1983). During treatment, he used crude electromyographic (equipment to monitor patient's muscle tension level). Progressive Muscle Relaxation is a technique based on tensing and relaxing muscle groups in a specific order. Starting with the muscles of the feet and ending with the powers of the face. It is essential to focus on the tensed and relaxed muscles of the body at a given moment. It helps you learn about the body and teaches individuals to regulate unnecessary muscle tension in everyday situations. PMR focuses on the natural relationship that reducing muscle tension affects the nervous system, reducing the level of stress, anxiety, and fear.

Schultz autogenic training, also called autogenic training, Johannes Shultz [26] developed it in 1932. It uses methods used in Yoga, hypnosis sessions, and zen meditation. All mystical and religious aspects are omitted in his theory. This training involves inducing a sense of warmth and heaviness in various body parts by describing this state; induction has a positive effect on the autonomic nervous system, which causes a state of relaxation and loosening. One example is repeating to oneself, "I am completely peaceful."

Breathing exercises [27] is another relaxation technique is controlling breathing. Calm, deep breathing helps to calm the heart rate and control emotions. During breathing techniques, diaphragmatic breathing is usually used.

Yoga [28, 29] is a relaxation technique that combines the body, breath, and mind. It leads to achieving inner harmony and balance. In addition, many scientific studies show that relaxation through Yoga can reduce stress, anxiety, and depressive symptoms.

Visualization [30] is a relaxation technique based on calming exercises and visualizing self in the form of a restful 'movie.' It could be imagining the sea, a forest, sunlight, and colors. This technique concentrates on the brain and does not distinguish between real and imagined images. It can help gain confidence in

a personal way and regain inner peace. The Visualization technique focuses on positive images in the mind that are associated with comfortable factors for the individual. There are several types of visualization techniques, including: One of the Visualisation techniques, Guided Imagery, is based on imagining places that evoke positive emotions, such as the forest or ocean, as mentioned above. Another technique is Visualizing a Goal, where a person creates an image of achieving a goal. Finally, Compassion Meditation focuses on promoting positive emotions, meditation, and invoking compliments about oneself.

Meditation and mindfulness [31, 32] are mind exercises designed for people who feel they cannot cope with their stress and negative emotions. These terms are used interchangeably, but it is worth noting that mindfulness is not only a relaxation technique but also an approach to life that focuses much more on acceptance of reality, learning about one's own emotions, and better contact with the body. Many previous scientific studies have proven the positive effects of meditation and mindfulness. Regular practice alters brain activity, aiding in the reduction of stress, mood disorders, and anxiety. MBSR, or Mindfulness-Based Stress Reduction, is one of the area's initial training.

This technique was created in 1979 by Dr. Jon Kabat-Zinn [33]. Worldwide, more than 200 medical centers offer Mindfulness-Based Stress Reduction therapy. These clinics provide MBSR, which is based on mindfulness techniques, and meditation and include simple stretching and posture correction exercises. It was created to deal with stress and is also often used to treat certain conditions such as depression, anxiety, chronic pain, and skin or immune disorders. According to scientific studies, MBSR intervention is low-risk and helps patients control their depressive or anxiety symptoms. Still, there is insufficient research to qualify Mindfulness-Based Stress Reduction as a proven intervention for chronic illness and pain. Instead, it may be a complementary or supportive method and intervention for stress management and anxiety reduction.

Mindfulness-Based Cognitive Therapy (MBCT) [34] was developed by therapists Zindel Segal, Mark Williams, and John Teasdale. It is an extension of classic MBSR and is used mainly with patients suffering from depressive disorders, primarily to prevent symptoms' recurrence. MBCT combines cognitive behavioral

therapy (CBT), meditation, and mindfulness.

2.2. Virtual Reality

Virtual Reality is a three-dimensional, computer-generated image. It can present objects, events, and the environment with some elements the user can interact with or use. It is based on the concept of the actual or utterly fictional world. The first attempts to fill the entire field of view of the recipient took place in painting; to set the recipient in the center of the painted events. In 1828 English physicist Charles Wheatstone [35] built a stereoscope device to view spatial images. Placed in it were two photos taken at different angles so that the brain processed the two-dimensional images into a three-dimensional plane. Precisely on this principle, the current VR glasses work. The first work on Virtual Reality technology, which will give the impression of being in another reality, began in the sixties. Only in 1965, a breakthrough discovery was made by Ivan Sutherland with the project The Ultimate Display [36], which is considered the first HDM system (head-mounted display).

Jaron Lanier [37], who created the term Virtual Reality, in 1984, founded the company VPL Research, which produced and sold the first VR glasses, which resemble the current gaming helmets. The solutions used by Lanier are still used today. Although VR technology allows users to achieve outstanding results today, a few components still need improvement and enhancement.

The most critical assumptions of VR technology are the creation of a technology that will make people feel natural and authentic. Therefore, Virtual Reality is used primarily in entertainment, presenting 360-degree movies or Virtual Reality games in which the user not only takes part but practically becomes a part of the virtual world. VR games are mainly based on player immersion via a head-mounted display or headset and one or more controllers. Virtual Reality revolutionized the gaming and amusement sectors, and as a result, many companies, such as Sony, Samsung, HTC, Oculus, and Google, are investing considerably in VR systems. Recently, many innovative solutions were invented, such as haptic suits, headphones, or special gloves to support VR technologies. Thanks to them, VR can stimulate our senses more intensively, positively affect the quality of the

experience, and support the creation of the illusion of reality.

Furthermore, virtual reality is supposed to evoke in users a natural experience that reflects facts as accurately as possible and is the ideal solution in cases where the implementation, in reality, could be extremely expensive or particularly dangerous. Therefore, it has found its application not only in the fields of entertainment but also in the context of professional training [38] (for training pilots, conducting surgery classes at medical schools). Again, it allows gaining valuable experience safely and economically. Likewise, virtual reality is a great educational tool; it will enable individuals to explore any event in the history of society through VR applications. Presently, on the market, the Discovery VR app[1] allows one to explore the world. In addition, users can view a variety of documentaries from a first-person perspective, with narration to guide them through the journey, which gives a unique VR experience. Furthermore, the VR Museum of Fine Art[2] provides viewing of room-scale, world-famous paintings and sculptures in virtual reality.

Virtual Reality also applies in therapy, treatment, and supportive therapies. It uses interactive and immersive simulation as a mechanism to spread psychological or physical treatment. These therapies have become very popular in recent years, and thousands of research studies are focused on improving the capabilities of this system. For instance, a growing field of research shows the impact of VR on the development of social skills for individuals on the autism spectrum (ASD) [39]. Results show that VR entitles minors with ASD to rehearse social skills that are challenging for them in a safe, virtual, non-threatening atmosphere. On top of that, they can repeat assignments continually.

Furthermore, one form of therapy using a VR environment is Virtual Reality Exposure Therapy (VRET) [40–42]. The use of VRET for medical purposes has been studied for about 20 years. Virtual reality exposure treatment is technology-based exposure therapy, an extension of the systematic exposure module of cognitive therapy. It aims to help reduce the severity of nervous reactions used to treat anxiety disorders, panic disorders, phobias, and post-traumatic stress disor-

1 https://www.oculus.com/experiences/gear-vr/773639796071241/

2 https://www.viveport.com/3a7fbcc0-5bcd-4ba3-81b7-0662c1247e12/

ders. The patient, during VRET treatment, is exposed to the various triggers in a controlled and safe VR environment. Therefore, VRET can harmlessly recreate disturbing, traumatic, or stressful scenarios and give an atmosphere similar to the person's experience.

2.2.1 Virtual Reality in Relaxation Techniques

Since VR is a platform that enables users to be immersed in an alternate space, previous works have applied immersive biofeedback for various applications. For example, researchers have also explored its uses for skill transfer, multi-sensory feedback, etc.
The DYNECOM VRE (DYadic NEuro-COMpassion) [43] is one example of an system focusing on meditation and well-being in Virtual Reality. The proposed

Figure 2.1 DYNECOM VR

approach is based on an immersive social meditation environment and two amplifiers to collect the psychophysiological signals for the biofeedback. Inspiration for this project was from the famous mindfulness meditation methods, loving-kindness meditation (LKM), and compassion meditation (CM). These techniques are constructed on:
LKM - building unconditional empathy toward others.

CM - arousing sympathy towards the needy, with a willingness to help.

The above mentioned study experiment was conducted on 72 participants aged 19 to 50. In The DYNECOM VRE system, both users were represented by statue-like avatars that sat in a circle with four other statue-like avatars. The avatars of the experimental participants were surrounded by statues and connected to another user's figure by a pathway or a bridge (as the idea of 'connecting' two users). The cited study showed that even a short-term intervention with mindful-

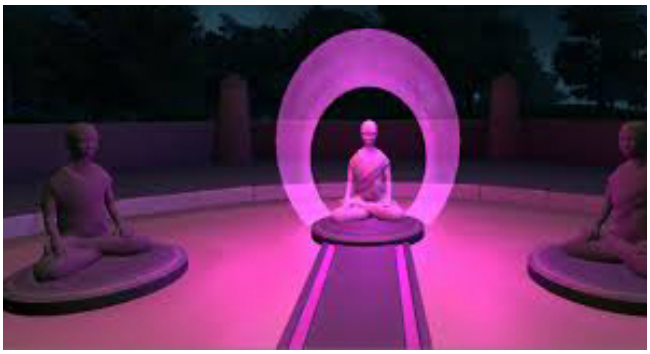

Figure 2.2 The user's view in the DYNECOM VRE.

ness techniques leads to increased empathy in individuals. Users felt much more sympathy towards the other participant than an inanimate statue.
The user's breathing speed was envisioned as the motion of a pulsating aura and unhurriedly enlightened the bridge or pathway. Empathy-related motivation toward the other participant, calculated from the users' EEG asymmetry, was visualized as a colored indicator in the bridge, track, and aura. The color visualization of electrical brain activation ranged from green (withdrawal motivation, low empathy), to yellow, orange, red, and pink (highest approach motivation, most elevated compassion), with a glowing effect in the bridge sidebars as an indicator of synchronization Frontal EEG Asymmetries between users.

The experiment investigated how the visualization of shared biofeedback affects empathy toward the other participant and synchronization between physiological activity. In the other hand in the second system, ZenVR [44] authors focused on learning meditation in a Virtual Reality environment. It is divided into two programs: teaching and background experiences. First, the individual obtains the

relevant knowledge in meditation, secondly they practice. Each stage of learning in the system presented replicates Bransford's learning model. The meditation technique is based on learning proper breathing, posture, and attention. The

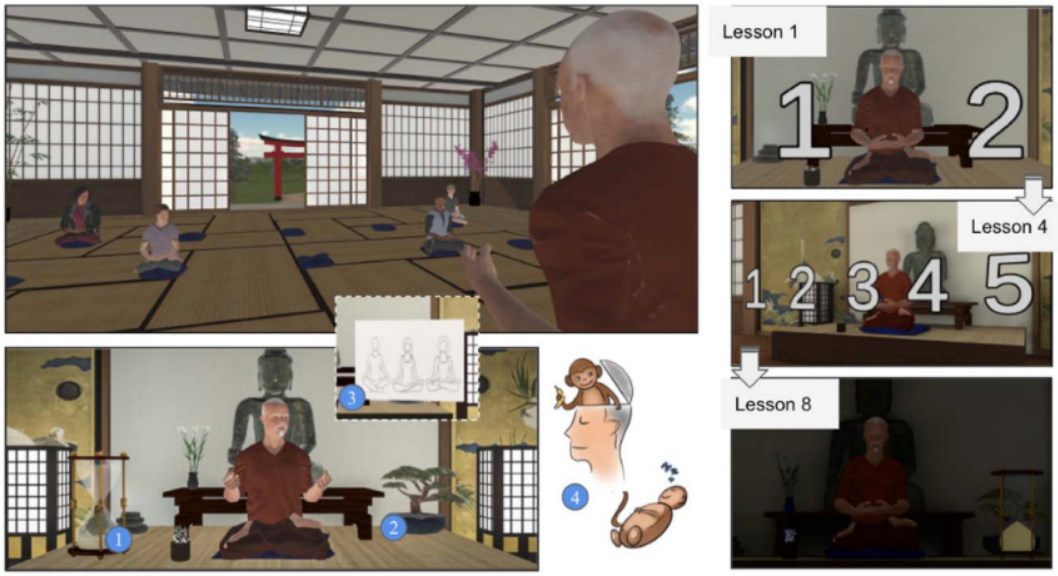

Figure 2.3 ZenVR Learning Environment

academic study omitted the use of Biofeedback due to their desire to focus on the content of the curriculum. They were concerned that users would attach more priority to the Biofeedback than the meditation techniques themselves. In the ZenVR system, knowledge and instructions are given by a virtual instructor.

The investigation cited papers suggesting that the presence of an instructor can increase novices' conviction and devotion to meditation practice. In addition to the tutor's content, further pedagogy was given through visual diagrams. Nature-related components were also attached to enhance the meditative experience, such as weather transformations and natural features like an evergreen. The advancement was shown by a bonsai tree that grew with the individual improvement. The study was conducted on 15 novice meditators as participants in a 6-week study. The dynamic elements in VR made the experience more realistic and immersive. The academic research found quantitative indicators of increased meditation ability after completing eight VR lessons.

Additionally, participants reported meditating on their own between visits and after the study and involving the techniques in their daily lives. ZenVR, as a VR learning environment, contributes to understanding the journey from a beginner to an experienced meditator. It has been demonstrated that VR can teach users to meditate independently and use the discovers in their routine outside the virtual environment.
RelaWorld [45] is a Neuroadaptive augmented reality meditation system. It is a hybrid of Neurofeedback and relaxation procedures, providing neophytes with an easier-to-understand design and delivering experienced meditation practitioners additional significance. Using the VR headset, users can levitate while committing meditation practices. The approach also measures real-time brain activity

Figure 2.4 The RelaWorld setup

via EEG and calculates estimated concentration levels and overall relaxation. The experiment was conducted under three conditions:
(a) Control Condition (CC) where the participants followed the meditation exercise on a computer screen without a VR headset or Neurofeedback
(b) VR headset without Neurofeedback
(c) both a VR headset display and Neurofeedback. Based on these criteria, in the system were Point Focus (PF) meditation and Body Scan (BS) meditation as forms of focused attention (FA) meditation for the study.

An experiment was conducted with 43 users between the ages of 20 and 48. The RelaWorld system was proven to induce more profound relaxation and meditation levels compared to a setup without the Virtual Reality system. Additionally, it

was reported by the study participants that Neurotherapy provides a heightened sensation level.

2.3. Emotions and Physiological sensors

Physiological sensors provide a fascinating prospect to measure human physiologic parameters in real-time in an infinite manner. These types of sensors measure microelectromechanical (MEMS), biological and chemical sensing, electrocardiogram (ECG), electromyogram (EMG), and an electroencephalogram (EEG) [46]. Physical and chemical sensors are often used in academic research and clinical and well-being applications. Skin conductance sensors serves as the most well-known

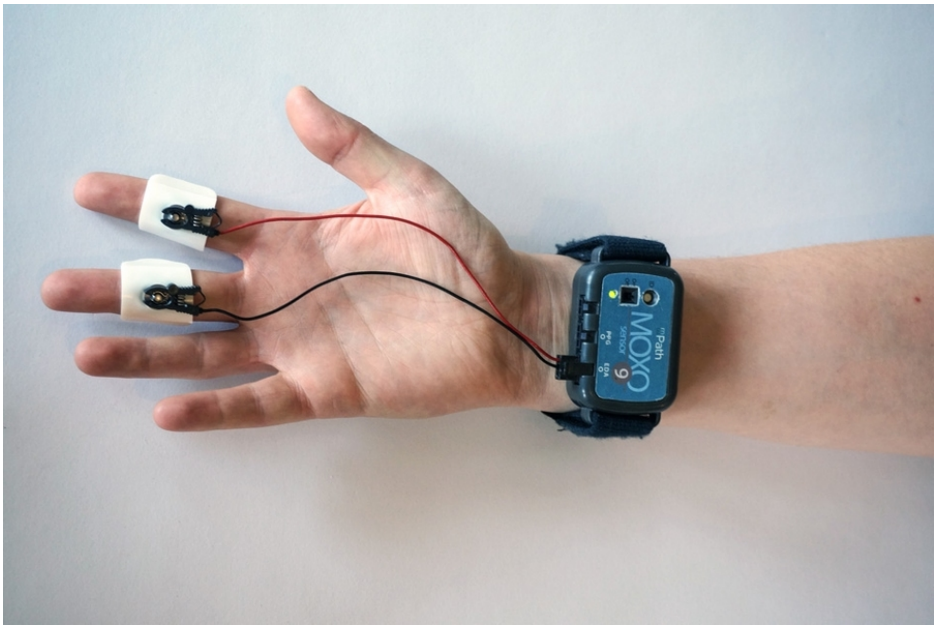

Figure 2.5 mPath's MOXO sensor

measurement in psychophysiology, which reflects the stress response, emotions experienced, and activity level. The sensor is used in stress therapy, anxiety, relaxation, and sports medicine. It measures changes in sweating caused by increased or decreased stress levels, skin conductance response (SCR), arousal by a given stimulus, and electrodermal skin activity in micro-Siemens (µS) units.

The ECG sensor is used to perform electrocardiography. The ECG amplifier measures the electrical activity of the heart. It allows the recording of one signal from one channel. The sensor measures HRV (RSA), the variability of the heart rhythm. The electrodes of the sensor are placed in the region of the heart muscle.

Using optical techniques, a photoplethysmograph (PPG) mesures oxygen saturation level (Sp02), and a pulse oximeter can measure the change in arterial blood volume with each pulse.
Some of the emotions and physiological sensors mentioned above have been used in numerous scientific papers. Below are outlined projects using these systems, which also served as inspiration for our prototype.

Your Body of Water [47] is system from a research paper focusing on the aesthetic use of biofeedback data to enhance participants' awareness of their bodies. The system relies on a display that wirelessly gathers heart rate data through a 3D camera and then envisions it as water proceeding on the screen. As the heart rate enlargements, more extensive and more rapid waves materialize on the water. Conversely, the waves become lifeless and smallish as the heart rate declines. The research question was whether the above-described approach could encourage embodied somaesthetic introspection. By exhibiting the heartbeat in real-time,

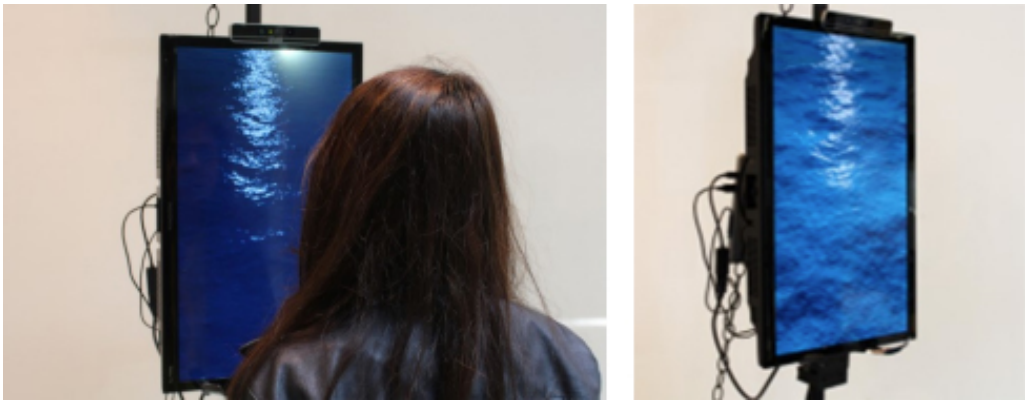

Figure 2.6 Your Body of Water

they desired that the individual taking part in the experimentation would concentrate their attention on internal reflection regarding their well-being rather than clearheaded observation of the heartbeat. How demonstrating the heartbeat in

an aesthetically engaging way, in this case, waves can support participants reflect on the processes inside their bodies. Over their experience and felt states.

They used a display and Intel RealSense 3D camera to create the Your Body of Water system. The RealSense 3D camera can collect an accurate heart rate signal, even if users stand sideways facing the lens. The programming part was done in Unity3D.

The primary intention of this study is to accomplish a hypothesis on how the participant feels their bodily experiences while giving space for subjective interpretation and introspection on their own experiences. Mattematics is an interactive installation that analyzes heart rate variability recorded over 2-3 minutes. The experiments aimed to support people in observing and experimenting with their biofeedback. To demonstrate the effect of combining calm breathing (as a form of relaxation) and shifts in the balance of the subject's autonomic nervous system. Relax and focus on optimistic feelings, compassion, kindness, appreciation, and to achieve inner peace. The study is designed to enable participants to better perceive bodily changes and feelings not only as 'mental' phenomena but also as a way of being. To embody them in an objectively measurable way. It is showing

Figure 2.7 Installation view of Mettamatics III

physiological changes artistically. Mattematics presented a project, an interactive art installation using heart rate to support the individual to create the connec-

Figure 2.8 Mettamatics III, in Wonderland exhibition, MoCA Taipei, Taiwan, 2012.

tion between breathing, heartbeat, emotions, and behavior. It was shown that in this type of work, it is imperative to allow dthe user to become familiar with the system. Gives them information on how it works and what it involves and then provides enough time to register, understand and reflect on the experiment.

StressTree [48] is a metaphorical visualization of the heart rate variability (HRV) biofeedback system. The presented project represents HRV more artistically and visually in the context of stress management. This design consists of biofeedback, heart rate variability, investigation, and visualization of the collected data.

The idea for this project came about because most systems that use biofeedback visualization in medicine do so numerically or with "serious" visualizations. This study used the metaphor of a tree. A tree-like visualization was designed that was responsive to HRV. During the experiment, heartbeats were measured and visualized under two conditions: 10 minutes of stressful work and 10 minutes of relaxation. The evaluation was performed in a simulated work environment. To avoid interrupting the participants' work, StressTree was displayed on the wall next to the desk. The experiment showed the impact of chronic stress on our health in a more meaningful and modern way.

In addition, the health of the tree revealed the level of stress. The study proved that StressTree could be a relaxation workout; participants in the experiment reported that the interaction with the biofeedback through this system was straightforward and sufficiently engaging and provided strong motivation to regulate their breathing pattern so that the visualization presented a "healthy looking" tree. In addition, they found that the aesthetic qualities of the visualization were essential to users' feelings during Biofeedback-assisted relaxation.

Diffusion [49] is the academic research of the relationship between human consciousness and electroencephalogram (EEG)-based brain-computer interfaces and interactive widgets that can render melody and synchronized graphic pictures by biofeedback. This project results from attempts to establish the relationship between human physiological information and immersive art. Diffusion is based on the ethical level of artificial intelligence (AI).

This study uses musical visualization to transform brain activity into aesthetic items like sounds or objects. The project presented above combines art and science as a starting point. It explores the visualization of brain activity and the

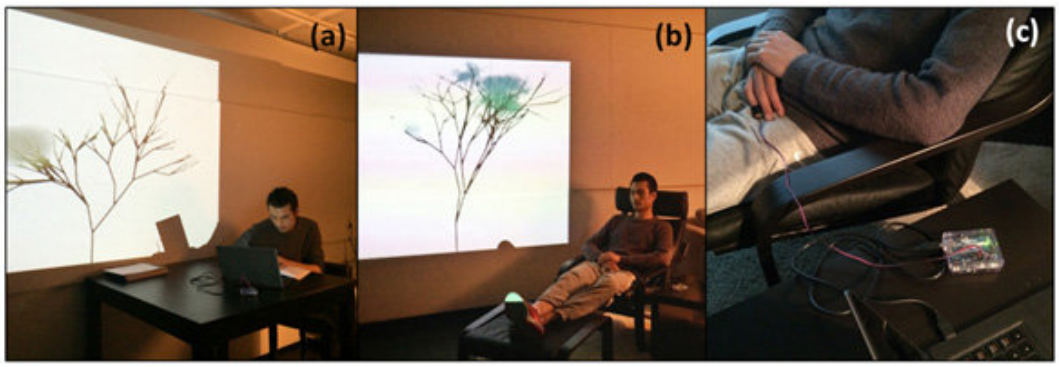

Figure 2.9 StressTrees, user study

interaction of biofeedback and real-world feedback, including how participants' brain activity can interact with the digital system and the relationship between embodied cognition and music perception.

Figure 2.10 Diffusion, a performance by Yuhao Yin

The goal is to analyze both sides of the interaction, especially the relationship between human brain activity, biofeedback, and the on-site experience of brain workers. Diffusion uses brainwave sensing technology to visualize and artistically present brain and body activity in a specific scene. It reveals the humanization of technology and provides a humanistic reflection on AI art and the revolution of science and technology in relational aesthetics. The project uses an interactive installation projected on the wall and brain waves taken from neurofeedback.

The authors' main goal was to create an interactive installation, in which they tried to transform immaterial things like feelings and thoughts into material things like images or music—representing human emotions and thoughts in an artistic and individualized way through artistic interaction installation. It is about bringing human consciousness into creative space[3].

3 Bransford's learning mode `https://newlearningonline.com/new-learning/chapter-6/supporting-material/bransford-brown-and-cocking-on-how-the-brain-learns`

Chapter 3
Concept Design

The following chapter gives an overview of the proposed concept based on previous chapters' findings. It will illustrate the system development process, explain the name behind "Transcendental Avatar," and implement approaches used to create the system. Also, there will be a presentation of how our projection came to be, and its first forms.

3.1. Design Process

The Transcendental Avatar is a concept that centers around stress relief to support relaxation techniques and manageable anxiety. Our prototype is a system using bioresponsive avatar of the self in VR that allows the participant to reflect, understand, and improve their cognitive and emotional states. In our prototype we are using biofeedback to create a representation of ourselves.

Following today's situation, stress is a severe enemy of modern society. It has even gained the name of the "disease of the century" because the developing civilization has significantly increased the scale of harmful stimuli - stressors [50]. It is very often the environment we live in - large cities, with noise, haste, exhaustion, hard work, inability to meet the requirements, unfriendliness, or fear. All these factors work together to create a situation where a person cannot discharge the accumulating stress. The signs of critical stress include emotional agitation, increased blood pressure, increased heart rate, breathing, and dry mouth. These symptoms are caused by the stimulating effect of stressors on the secretion of hormones, e.g., adrenaline, vasopressin, prolactin, or endorphins. Long-term stress is hazardous for us. It arises under an increased stressor or when it works for a long time.

One of the most effective ways to cope with stress is to relax. When a person rests and feels safe, the parasympathetic nervous system takes control of the body - it is responsible for the work of various organs and glands. Relaxation can counteract the adverse effects that stress has on us. Relaxation has a beneficial effect not only on mental but also on physical health. Taking into account all the factors mentioned above, we started creating a prototype with the hope that our system in the future can be an assistive tool for mental health and open the door for future research on bioresponsive avatars.

3.2. Concept

3.2.1 Transcendental Avatar

In order to better understand the operation of our system, we should first explain the meaning of the name we chose for our prototype; Transcendental Avatar.
The definition behind Transcendental or Transcend comes from the words 'climb over' or 'beyond, above' in Latin. Transcendental can also be described as; supernatural, metaphysical, or beyond the human, mortal experience. When something is transcendental, it is above ordinary, day-to-day experiences. It might be religious, spiritual, or esoteric. The term transcendental depicts a particular kind of meditation, a specific school of philosophy, and even a type of number in mathematics.

If something is Transcendental, it exists beyond the regular spectrum of the material universe experiences. On the other hand, in Kantian philosophy (a unit of philosophy that follows the works of Immanuel Kant, who believed that rational beings have dignity and should be respected), it is necessary to experience and prior. As we wanted our prototype to 'move users' to an immersive world for relaxation purposes, where they can get away from reality, Transcendental seemed like the perfect name.

The second word, 'Avatar' has many definitions; in the most common and contemporary sense, it means an electronic image representing the user in a digital world. It can be a game or social media persona. Avatar derives from a Sanskrit word meaning "descent." When it first emerged in English in the late 18th cen-

tury, it referred to the descent of a god to the earth—generally, the incarnation in the earthly shape of Vishnu or another Hindu god. In Hinduism, Avatar also implies a manifestation of divinity or released soul in bodily form on earth; an incarnate divine teacher or someone who represents a type of person, an idea, or a quality.
Because we wanted to create a system where the user can feel like they are in another dimension, combining these two words seemed to fit the concept of an immaterial personification of our biofeedback in the nature-based VR environment.

3.3. Pilot Study

3.3.1 User Surveys

Before we started the primary prototyping process, a survey was conducted to decide on the aesthetic part of the design and find out about the general mental state. In the survey, 225 people participated, and the vast majority were women aged 25-34. First, participants answered a question about mental health status. The survey allowed us to find out in detail what the most significant mental health problems are. We constructed the question:
Over the past two weeks, how often have you been bothered by the following problems?
The most prominent responses regarding feeling worse every day, or almost every day, were mainly about being overtired, having trouble relaxing, and feeling anxious or constantly nervous. However, the situation is much better when it comes to being on edge or worrying too much about "small things".

The part of the interview about user well-being made us even more aware of the problem with a stressed-out society. A large number of users opined about daily stress, being anxious or being overwhelmed. As we mentioned in Chapter Two, in the section on stress, prolonged exposure to stress can lead to serious health complications. The survey that was conducted, in and of itself, provided additional evidence of the importance to create new methods to combat stress and anxiety.

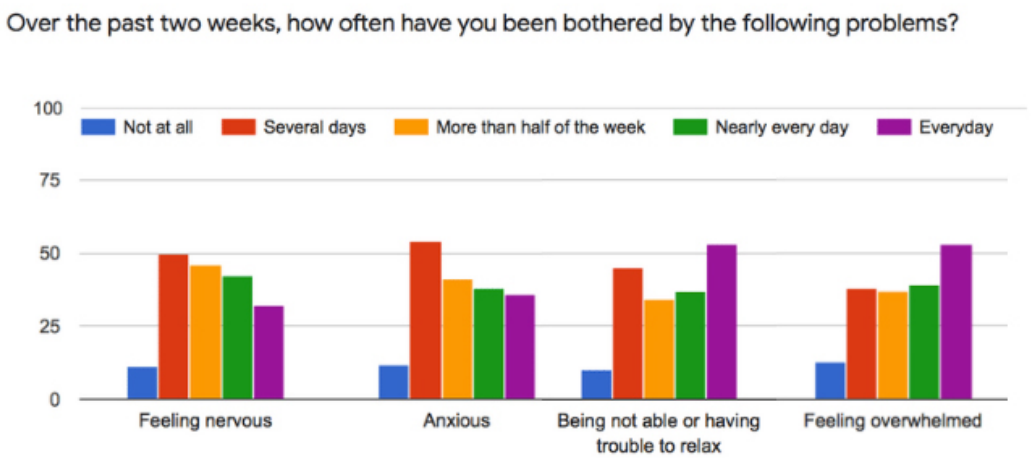

Figure 3.1 Pilot-study - mental health survey

3.3.2 Aesthetics preferences survey

In the next part of the survey mentioned above, we included questions about visual and aesthetic aspects. Our goal was to determine which colors positively affect relaxation and calming and whether warm or dimmed light has a better impact on inner peace. According to the responses of the survey participants, the

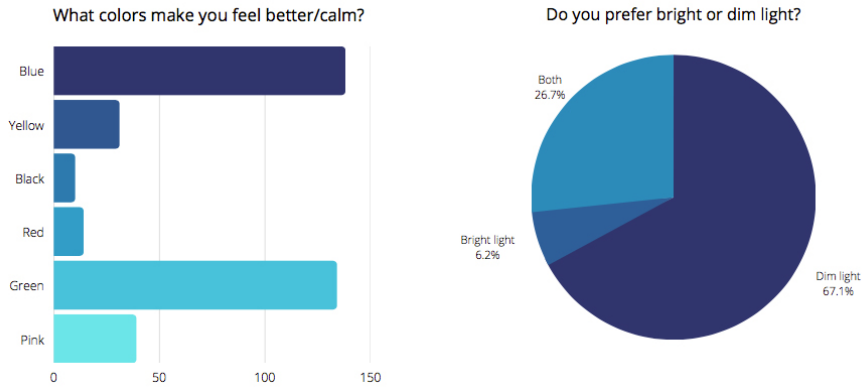

Figure 3.2 Color preferences survey

colors blue (138) and green (134) had the most positive impact. Pink (39) and

yellow (31) scored slightly smaller results.
In the next part of the survey mentioned above, we included two collages composed of various photos and graphics. Our goal was to determine which colors positively affect relaxation and calming and whether warm or dimmed light has a better impact on inner peace. The first collage included fifteen photographs related to nature: different types of the sky, northern lights, stars, flowers, rain, and greenery. The top choices of the photos were number 13, northern lights (11.3%),

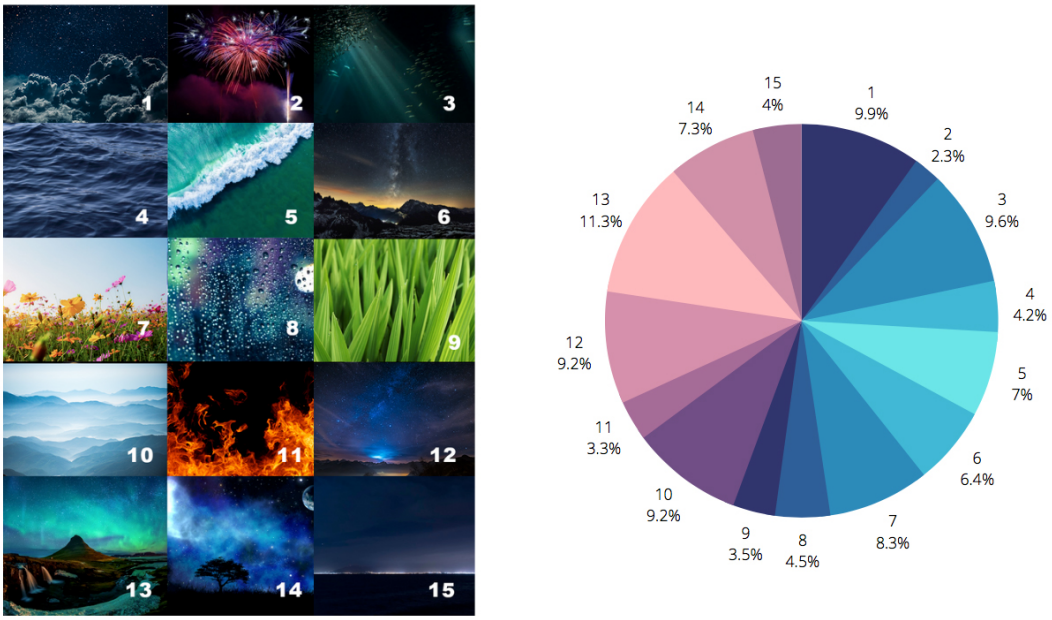

Figure 3.3 Nature-based photo collage from survey

1 (9.9%) portraying the night sky with stars and clouds, and 3 (9.6%) representing dark, underwater life. On the other hand, the number 10 (9.2%), hazy sky and mountains, and the number 12 (9.2%) with the night sky, achieved equally high results. In the case of abstract pictures we proposed in the survey, the most preferred image was number 2, portraying pink and blue particles (14.3%), 7, a deep blue galaxy (13.2%), and 1 showing purple particles (12.3%). The survey helped us define the look of the proposed system and provided significant insight into the whole aesthetic.

After receiving the interview results, we began the aesthetic part of the pro-

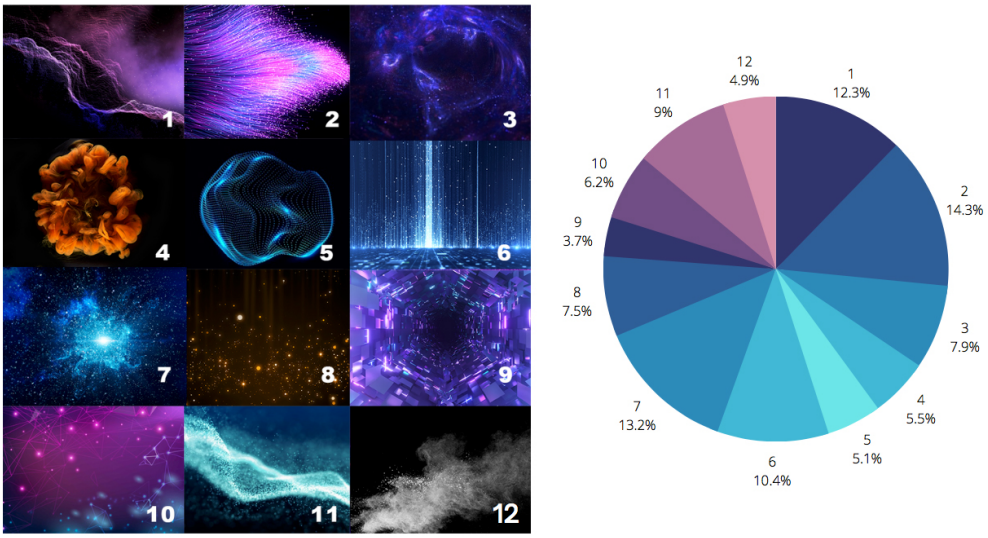

Figure 3.4 Abstract pictures collage from survey

totype. The survey helped us determine the future appearance of the proposed system, both in terms of the built 2D and 3D prototypes. In addition, it significantly impacted the selection of appropriate colors, background graphics, creating the world, and the entire avatar design.

3.3.3 Target Persona

The primary user of our system can be anyone, regardless of age or gender, who needs relaxation, personal space, detachment from reality, and stress reduction. According to virtual reality user statistics, the number of people using this tech has been on the fast track since 2015. One hundred seventy-one million people worldwide use VR today, and those aged 16-34 are more likely to use virtual reality. [1]

1 https://99firms.com/blog/virtual-reality-statistics/gref

3.4. Prototype 1; Abstract Body Shape (2D)

In the initial phase of prototyping our project, we focus on creating an interactive art installation, with displaying an animation on a wall using a projector. This system's leading interactive element is the participant's silhouette create by responding to biofeedback particles.
The inspiration for this project came from earlier works that we presented in the Literature Review. For example, Diffusion [49] or StressTree [48] used the interactive art installation to display participants' biofeedback visualization for stress relief. In Diffusion, neurofeedback has been turned into particle-based abstract visuals to show the relationship between human brain activity, biofeedback, and the on-site experience of participants—process, participation, and interaction between these three factors. In the case of StressTree, they use tree-based metaphorical visualization of the heart rate variability (HRV) biofeedback system. Participants in the experiment reported that to get the visualization presented as a "healthy looking" tree, they were strongly motivated to regulate their breathing patterns and relax. Seeing both projects' positive and prospective results, we decided to

Figure 3.5 Prototype 1; Abstract Body Shape (2D)

try to use this method to create our prototype. We chose to operate programs

like TouchDesigner and Adobe After Effect to create the prototype and the art installation. In TouchDesigner, we created a whole system, while Adobe After Effect supported us with additional aesthetic elements and animations. For hardware, we used a projector to display the image on the wall, sensing devices for collecting user's biofeedback, and Microsoft Kinect Azure for body motion tracking and depth data. We demonstrated the biofeedback collected in real-time. In

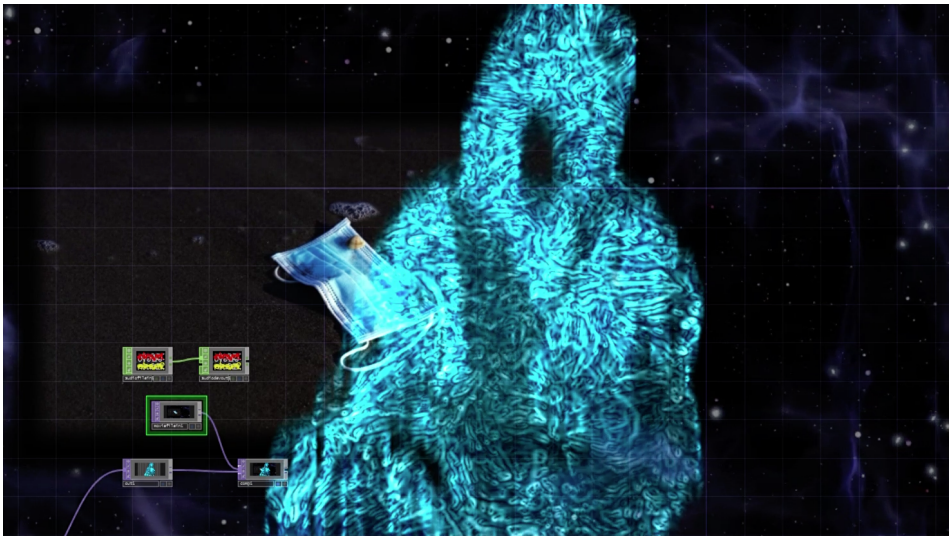

Figure 3.6 Prototype 1; Abstract Body Shape (2D), TouchDesigner system test

the simplest terms, the system's operation can be described as the user putting on the left-hand HRV / EDA sensing device. Then, the data is sent to the computer. At the same time, Microsoft Azure Kinect transfers depth maps and body motion tracking to software. In TouchDesigner,the program creates an avatar composed of abstract shapes that respond to changes in biofeedback (from sensing device) and react to the user's movements (captured by kinect). Finally, everything is projected onto the wall/screen by the projector.
In our study, the participant's shape on the wall, referred to as the 'Avatar,' was made of blue three-dimensional spheres that moved (speed and shapes) with the biofeedback data we received. Sound effects were provided through headphones. The user could listen to different types of sound and observe changes in the avatar. It was meant to relax, de-stress, and help to focus on changes in emotions.

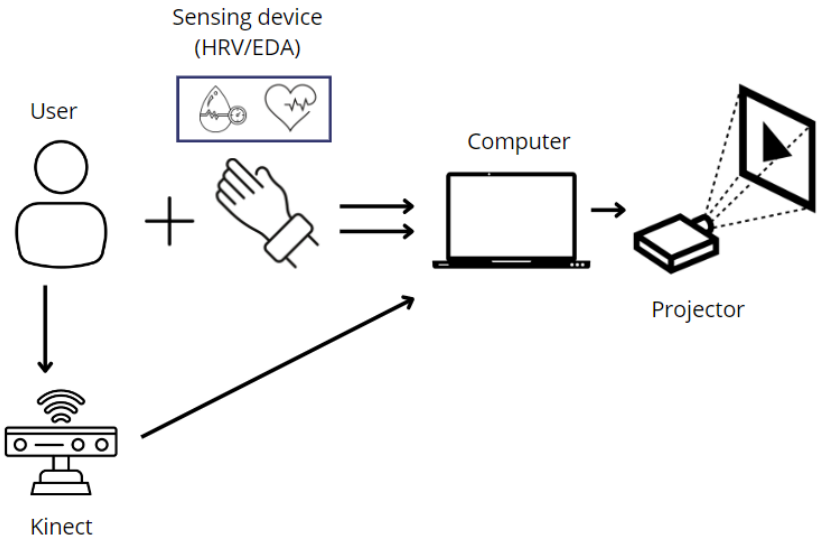

Figure 3.7 Prototype 1; Abstract Body Shape (2D), system

3.4.1 User test

User Study Prototype 1; Abstract Body Shape (2D) was performed twice, once indoors at the university project room and a second time during an indoor exhibition with around 15 participants. In the case of the first user study, we projected the prototype using a projector as intended, but in the exhibition, we focused on the large screen due to the bright place's light disturbing the image's color and visibility. In both cases, the users sat on the chair; they were put on a wristband measuring the EDA and HVR and headphones. Then, they watched the biofeedback displayed in the Avatar for several minutes. After the experience, we conducted an interview. Although the experience was met with enthusiasm and a cheerful aesthetic feeling, we faced some significant limits for the main goals of our research. First, from the technical side, the abstract 3D object inside the participant's body shape created in TouchDesigner was a heavy load on the computer system. Despite many attempts to improve performance, the displayed animation was delayed several seconds. Second, we received as well important comments from users:

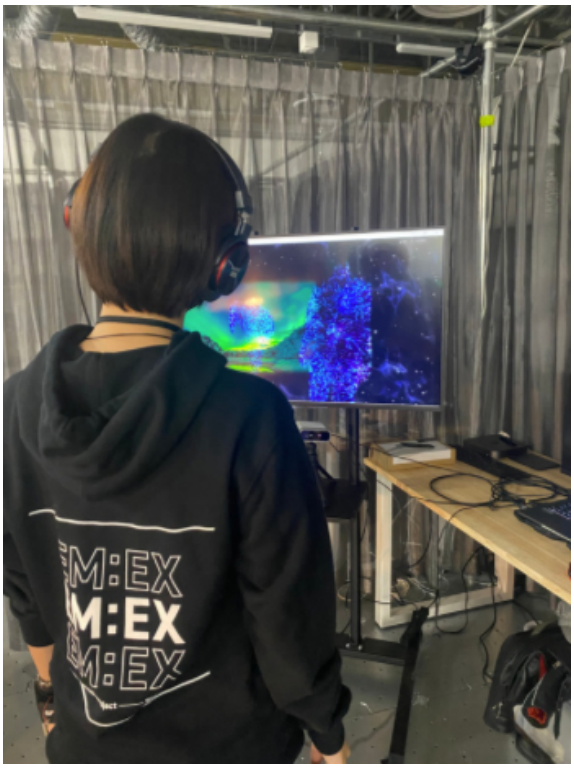

Figure 3.8 Prototype 1; Abstract Body Shape (2D), first user test

Figure 3.9 Prototype 1; Abstract Body Shape (2D), TouchDesigner system

1. Because the prototype was displayed in a public space, there were too many distractions, which negatively affected the relaxation result. Participants can't focus on relaxation.

2. The abstract forms inside the Avatar were too dissimilar from the human appearance, making them unable to identify with the personification of participants' emotions.

3. The art installation did not give the impression of being in another world/dimension. Users felt and knew that they were in a public place. However, it did not provide them with a sense of intimacy and connection with themselves, which negatively affected the results.

After analyzing the results of the above user study, we decided to create a second version of our prototype.

3.5. Prototype 2; Human-like (2D)

The second version of the prototype we constructed is named Prototype 2, Human-like (2D). The complete structure of the procedure from the previous version re-

Figure 3.10 Prototype 2; Human-like (2D) test

mains identical. The only thing that has changed, based on the feedback received earlier is the visual aspects of the prototype. Unlike the version mentioned above, we've given up the abstract shapes and create a human-like avatar. In TouchDesigner, we have constructed a user-like avatar by using the Point Cloud technique. The particles inside the Avatar responded with acceleration and colors to changes in the user's EDA and HVR.
Furthermore, we abandoned using the projector at the latest stage, concentrating instead on the large screen. Another limitation mentioned in the user study, was distracting the user from relaxation and focusing on their Avatar due to too many stimuli. Therefore, for Prototype 2, Human-like (2D), we decided to conduct an experiment in a close space, darkened room, where the user could focus only on their presence and experiences. The second motivation we wanted to experiment with in a dark and soundproofed room was to construct a location where the participant can feel detached from reality and concentrate solely on inner feelings and relaxation.

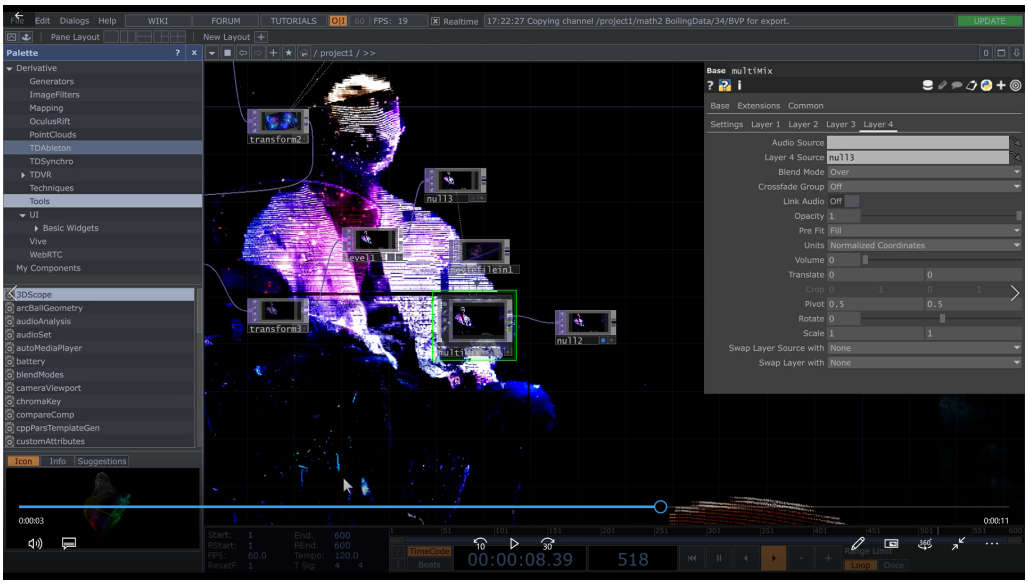

Figure 3.11 Prototype 2; Human-like (2D) and TouchDesigner system

3.5.1 User test

Prototype 2; A human-like (2D) user study was conducted in a media studio, a darkened and soundproofed room. As mentioned earlier, the decisions were influenced by the limitations from the first user study. In the second rendition of the prototype, we wanted to provide a space where detachment from reality would be much easier and, thus, a relaxation process. To make the user feel closer to his Avatar and be able to concentrate all his attention on it.

Figure 3.12 Prototype 2; Human-like (2D), user study

3.6. Prototype Refine

We considered all the data obtained during previous user studies and interviews for the next prototype version. We decide to choose Virtual Reality as a tool to make a prototype, as a more accessible system to help us achieve our goals. In later stage, we also abandoned the use of TouchDesigner (TD) for visualization content due to its limited capabilities in the context of Virtual Reality and the previously mentioned heavy load on the system.
TouchDesigner was only used as a program to filter and optimize data from sensing device. Instead, we focused on using Unity 3D, which allowed us not only to

expand the 3D world and create a system for Virtual Reality but also to optimize the system, thanks to which we got rid of the problematic lag in Avatar's response. Also, the extensive access to the Unity GitHub repository allowed us to use more complex variations in terms of special effects. For example, we used a plugin for Unity created by Keijiro Takahashi [2], which generates the visual effects that gave Avatar's much more pleasant and stimulating looks or OscJackVS plug-in that allows us to transfer data from TD.

3.6.1 Interview

This interviews with users allowed us to sketch the final version of the prototype. In the refine version of our design, by moving the project to virtual reality, we were able to create a more emotionally impactful environment that allowed users to move mentally into another dimension with their individual Avatar. Once

Figure 3.13 Initial version of Virtual Reality prototype

again, we conducted an experiment using both systems, Prototype 2; Human-like

2 https://github.com/keijiro

(2D) and new Virtual Reality version, on seven participants. Compared to the art installation, the participants expressed much more interest in Virtual Reality finding this system more appropriate, modern and accessible.
In contrast to the art installation experience, they felt a greater connection to the Avatar, and noted that it was easier for them to relax. Virtual Reality world, gave them a sense of intimacy and a sense of detachment from reality. After making this comparison of the two systems, we started to expand the prototype in Virtual Reality.
Also, in an interview conducted later, by using video clips of the art installation and the virtual reality system, additional twenty participants, were dominantly in favor of VR. They found this system to be much more interesting, intimate, and more eye-catching aesthetically. They also clearly opined that in a system using Virtual Reality it would be much easier for them to focus on their emotions or relaxation techniques.

3.7. Final Prototype: Human-like (VR)

In the Final Prototype: Human-like (VR), we present current version of Transcendental Avatar, a bioresponsive avatar of the self in VR that allows the audience to reflect, understand, and improve their cognitive and emotional states. Compared to the previous, inital Virtual Reality version, we have expanded the system with ten different backgrounds, three different avatar designs and the capacity to change the avatar color based on data from the EDA and HVR measuring device. The user will be able to experience their Avatar that reflects their physiological state in real-time. The transcendental Avatar's VR experience design depends on the user's personal Avatar and the emotional stimulus. To design the individual Avatar, we draw inspiration from the abstract representation of an individual's persona. We use the Microsoft Kinect sensor to capture the user's point cloud, then adjust their abstract rendition in VR using Touch Designer. When the cognitive load level is high, and the emotional arousal is low, the user appears to be more abstract and less colorful. Likewise, the Avatar appears more alive and full of color to depict low cognitive load and high arousal. After successfully implementing the Avatar, we looked into making it bioresponsive. A bioresponsive

Figure 3.14 Final Prototype: Human-like (VR), high particle-points, sunset background

Figure 3.15 Final Prototype: Human-like (VR),night sky background

avatar is an avatar that understands and responds to the user's cognitive and emotional state. Therefore, they were authorized to study the interplay between cognitive and physiological processes. They are increasingly used to identify emotional states or an individual's arousal state. A bioresponsive avatar is an avatar that understands and responds to the user's cognitive and emotional state.
In other words, for the Avatar to be bioresponsive, it needs to receive data from the user's physiology. We achieve this by sensing two main physiological signals; heart rate variability (HRV) and electrodermal activity (EDA). These signals have been proven to reflect the user's cognitive load and emotional state.
We used a custom sensing device based on ESP32 worn on the left hand. HRV is sensed via plethysmograph (PPG) with a sampling rate of 50Hz, whereas the EDA signal was sampled at 4.545Hz. These signals are streamed to a server software where we perform signal processing. For the HRV signal, an increase in perceived cognitive load increases both the parasympathetic and sympathetic components, which is reflected in an increase in HRV. For EDA, we observe its physic component, which directly correlates with emotional arousal. As we pointed out earlier, we abandoned using TouchDesigner for the most part and moved the entire project to Unity. Thanks to this, the system gained a three-dimensional character, ideally suited for Virtual Reality.

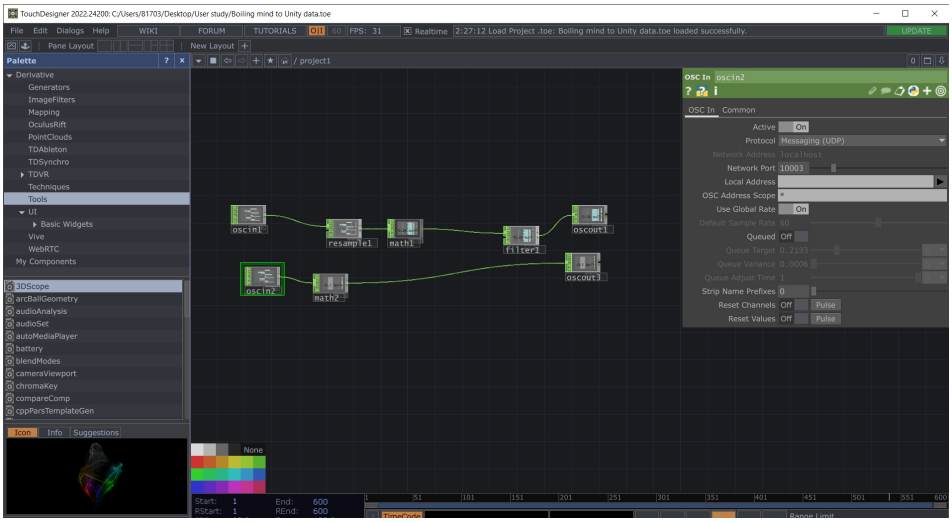

Figure 3.16 OSC-out and OSC-in from TouchDesigner

3.8. System overview

In this section, we will describe each element of our prototype's current and last version. Then, we will show how the prototype is technically built and which programs (software), hardware, and additional plugins we used. This will give a better understanding of the proposed system and it is functions.
Here are the basic guidelines of how the system works:

- Tracking sensors. In this prototype we use Microsoft Azure Kinect to capture point cloud data and body tracking data.
- Virtual Reality system created in Unity 3D game engine.
- Sensing device based on ESP32 collecting two main physiological signals: heart rate variability (HRV) and electrodermal activity (EDA).

3.8.1 Software, TouchDesigner and Unity 3D

In the case of the first two prototypes, Abstract Body Shape (2D) and Human-like (2D), which were presented as an interactive installation displayed using a projector and Microsoft Kinect Azure. The system was created in the TouchDesigner (TD). TouchDesigner is the node-based virtual programming language for interactive installation and multimedia content. This software allows the development of artistic projects in real-time. The program was designed by Toronto-based company Derivative. The main features of TouchDesigners are projection mapping, interoperability, and high-performance media systems. In addition, it supports VR, making real-time 3D and compositing, and keeps lighting and live shows. TouchDesigner authorizes the application engine and user interface to be constructed in one integrated environment. Unfortunately, the interactive form of the prototype displayed on the wall for both the first and second prototypes was insufficient for the user. It was difficult for them to observe their biofeedback and feel safe in intimacy with the avatar. There were also too many stimulants around for the participant to focus on relaxing. Taking into account the factors mentioned above, at the first moment, we tried to transfer the project to the Virtual Reality system in TouchDesigner. Unfortunately, the existing version does not authorize such complex projects, so we decided to construct the prototype

entirely in Unity 3D. Although we gave up on building the system in TD, we used this programming to send the date from the biofeedback device to Unity 3D.
To build a fully Virtual Reality experience interactive system, we used Unity 3D. Unity is the platform for creating three-dimensional (3D) and two-dimensional (2D) projects. It is professional software for both artists and programmers. In addition, it allowed the development of games, interactive simulations, and other experiences. As a result, Unity is one of the most used engines for developing Virtual Reality projects. Our prototype used Unity's High Definition Render

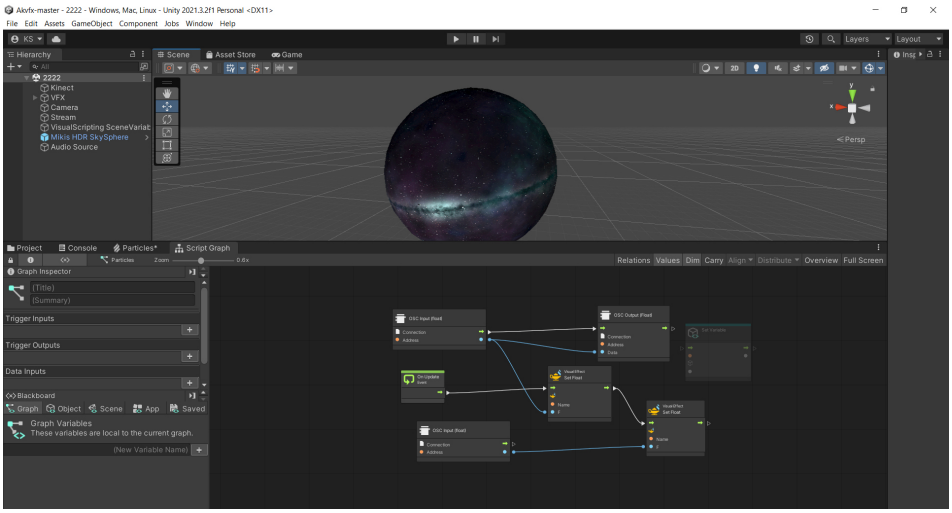

Figure 3.17 Unity3D OSC script graph

Pipeline (HDRP), first introduced in Unity 2018. It is compatible with VR, optimized for single-pass rendering, and operates Shaders and lighting units different from those in Unity's built-in render pipeline. For example, HDRP Shaders create a comprehensive variety of materials. Also, HDRP Materials support light emission, creating a self-illuminated visible light source. Visual Effect Graph (VFX) is used to create one or multiple high-quality Particle Systems, affect effects at diverse rates, and accomplish step-by-step simulation. One more essential feature of VFX is making sub-graphs of the Nodes or building properties to customize the instances used in the Scene. VFX enables the creation of visual effects using Node-based visual logic, and it can be used for simple, special effects and very complex simulations.

During our work in Unity, we used several plugins to make our prototype works:
- keijiro/OscJackVS it is an extension for visual script for handling Open Sound Control (OSC) messages. This plugin allowed us to send information to Unity from the biofeedback device via TouchDesigner.
- keijiro/Akvfx plugin that captures depth/color and point cloud data from Azure Kinect and connect them into tribute textures for using Visual Effect Graph.
We used as well several components from Unity Assets Store:
- SpaceSkies Pro, space skyboxes
- Galaxy Fire Skybox, themed skybox for your games and unity scenes featuring stunning nebula, stars, galaxies and planets, in a fiery orange and red color.
- GalaxyBox 1.0, skybox asset that contains scientifically correct scenes of galaxies.

3.8.2 Hardware

This subsection will describe the inventory of tools, machinery, and other durable equipment used to build the prototype. Additionally, we will explain how we used the equipment, the limits we encountered and how we made our prototypes from the technical side.

- **Microsoft Azure Kinect DK** combines developer kits and advanced AI sensors to achieve the most developed computer vision and voice models. It is a state-of-the-art imaging and speech device - a camera that makes the user himself a controller. It has a 12MP RGB high-resolution camera (12 Mpix), a depth sensor (1 Mpix), and a set of 7 "spatial" microphones. Kinect has a versatile design that combines advanced depth sensors and spatial mic array, and azimuth sensors in one with multiple modes, options, and SDKs. We can create applications connected to Microsoft's cloud and AI technologies with the Kinect. Depth sensing is essential in various applications, such as Virtual Reality (VR) and Augmented Reality (AR). We used Azure Kinect Body Tracking SDK for our technique to track the user's body and send the point cloud to our project.

- **Personal Computer** We were working on Galleria, Nivida Geforce RTX,

Intel Core i7 9th Gen. We chose a laptop to create our project, so that future user tests could be carried out in several places. The computer we chose was sufficient to create an application in VR using the Oculus Rift and Kinect, but due to the high load, after an hour of use the computer heats up too much, which causes lag.

- **Oculus Rift S** is a virtual reality headset. Rift S uses a single fast-switch LCD panel with a resolution of 2560×1440, which translates to an increase in pixel density from 456 PPI to 600 PPI and an 80 Hz refresh rate, down from the CV1's 90 Hz. The field of view is 115. The field of view has also increased from 110 degrees to 115 degrees. The Oculus Rift is mounted entirely on elastic Velcro straps. It has small built-in speakers facing the user's ears. The headset features software-only interpupillary distance (IPD) adjustment because it uses a single screen instead of dual displays. The main feature is a halo headband with better weight distribution, better light blocking, and more comfortable overall. Virtual reality is, as we mentioned earlier, the ability to move and interact freely in a virtual world. In practice, this means displaying a stereoscopic image for each eye separately, which gives a natural depth of vision and precise tracking of both the position of the head and the controllers held in each hand. Therefore, we decided that Oculus Rift S best fits our prototype because it is not very heavy equipment and is compatible with the software we used. It concurs with both Unity 3D and TouchDesigner.

- **Projector**, to the first prototype, before project became Virtual Reality surface, we used EPSON LCD PROJECTOR EB-1940W to display interactive installation on the wall.

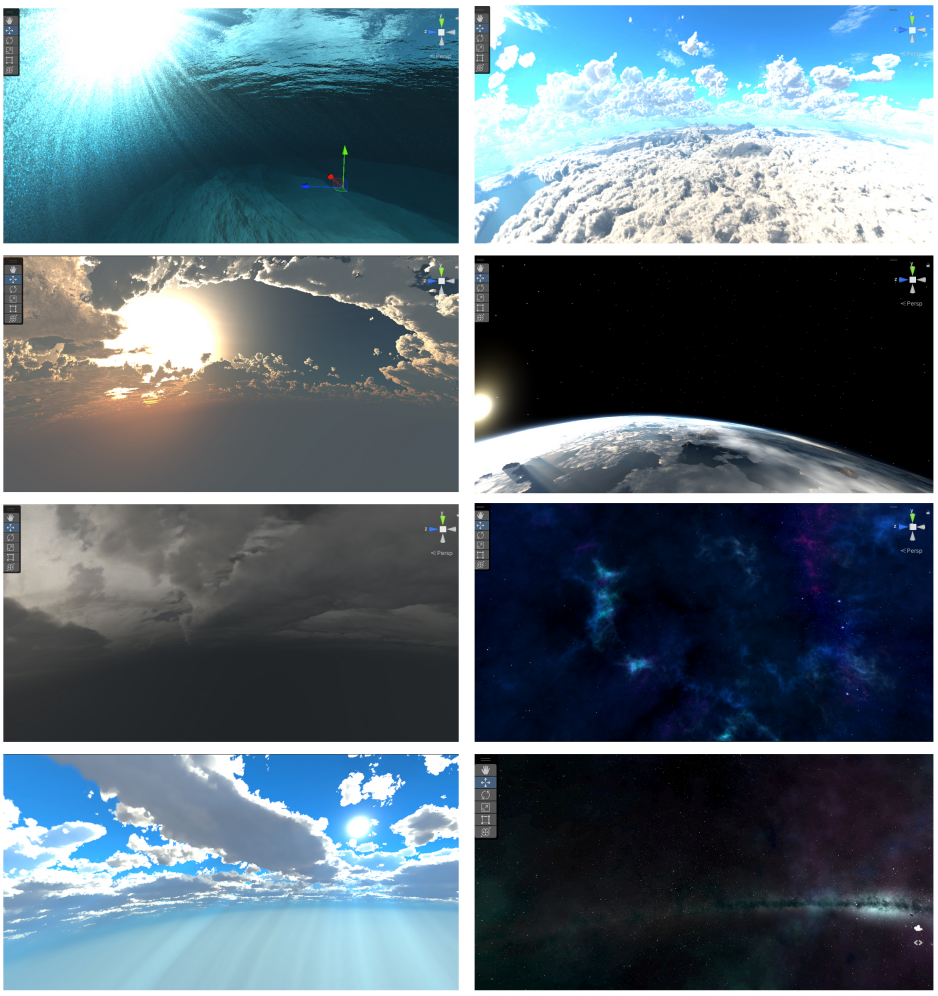

Figure 3.18 Different Skyboxes in Unity 3D

Chapter 4
Proof of Concept

This chapter will describe the proof of concept of the proposed system with an evaluation study on thirteen individuals. It covers the prototype experiment process, study findings, and discussion. Firstly, the evaluation method will be defined, and after this, we will detail the experiment's results. In summary, we will analyze and discuss the validation. This chapter will allow us to understand the results of the experiment, and give a general overview of how it proceeded, and what conclusions were drawn from it.

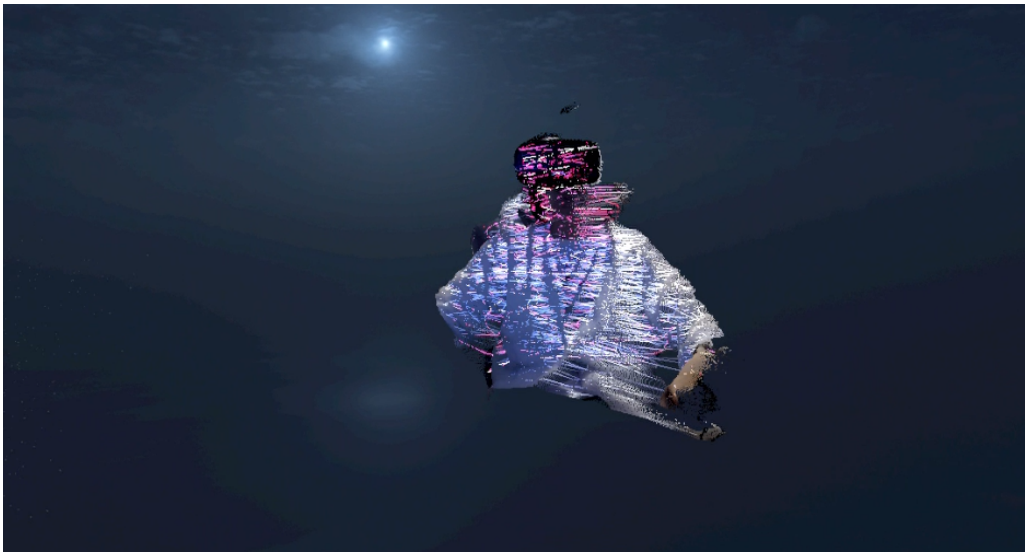

Figure 4.1 Low particle-lines, night sky background

4.1. Method

In this study, we conducted experiments to verify the validation of the design; immersive bio-responsive experiences allow participants to see their biofeedback personification. The purpose of this study was to conduct both quantitative and qualitative evaluations on how the presence of a self-avatar created from responsive particles can influence overall well-being, and the relaxation process.. Furthermore, we hope this experiment enables people to reflect on themselves more easily and can assist them with any relaxation processes in mental health concerns like stress or anxiety.
Although several studies related to relaxation techniques have previously been carried out in the Mixed Reality field, especially with a strong focus on meditation and related elements, within our experiment, we focus our attention primarily on the presence of the bioresponsive self-avatar in the VR system and its effect on relaxation or understanding one's own emotions. Our experimental procedures let participants experience each condition in a Latin square order. The research was carried out individually to ensure participants' calm surroundings without disturbing circumstances. The expected results of our experiment included a reduction of stress in participants through relaxation in a nature-based Virtual Reality environment.
The experiment conditions are three different avatar designs, high particle-points avatar, medium particle-squares avatar, and low particle-lines avatar in ten environments:

- **Ocean**
- **Four types of the galaxy** deep space, green and blue Nebula, sunrise in space
- **Five types of the sky** pink morning, deep night, sunset, sky during sunny day and raining clouds

4.1.1 Technical Implementation

We constructed this prototype for the Virtual Reality system using the Unity Game engine. The Transcendental Avatar's VR experience design depends on

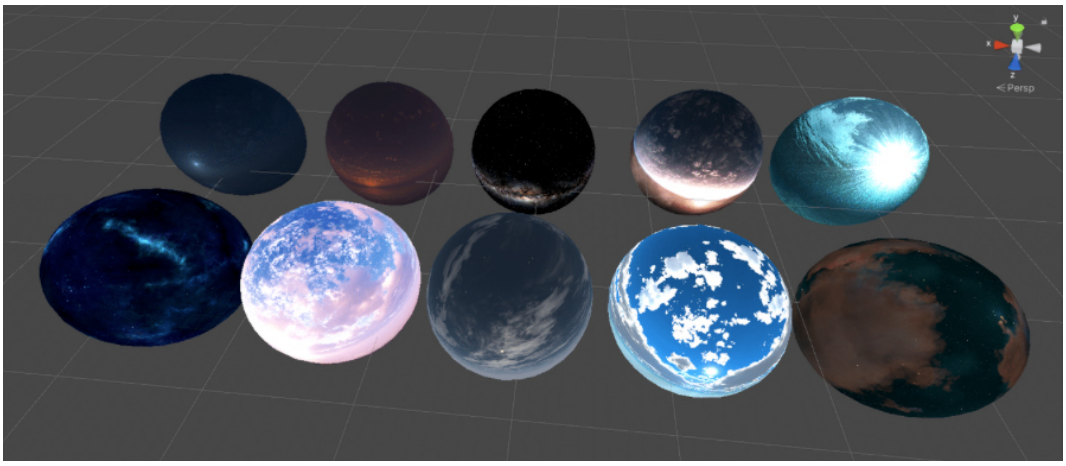

Figure 4.2 Various skyboxes

the user's avatar and the emotional stimulus. To design the user avatar, we draw inspiration from the abstract representation of a person's persona. We use the Microsoft Kinect Azure sensor to capture the user's point cloud. At the same time, we transmit from the sensing device two primary physiological signals, heart rate variability (HRV) and electrodermal activity (EDA), to the Unity 3D engine. These signals have been proven to reflect the user's cognitive load and emotional state. We used a custom sensing device based on ESP32 that is worn on the left hand. HRV is sensed through a plethysmograph (PPG) with a sampling rate of 50Hz, whereas the EDA signal was sampled at 4.545Hz. These signals are streamed to a server software where we perform signal processing. For the HRV signal, an enlargement in perceived cognitive load increases both the parasympathetic and sympathetic components, which is reflected in a growth in HRV. For EDA, we observe its phasic feature, which directly correlates with emotional arousal. When the cognitive load level is heightened and the emotional arousal is descending, the user's avatar materializes more abstract, more peaceful, and less colorful. Likewise, the avatar emerges more dynamic, fast, and full of color to depict low cognitive load and high arousal. To concoct VFX special effects, we use a Unity 3D plugin designed by Keijiro Takahashi. We used three different special effects for Point Cloud through Kinect. When the Unity engine received the data from Kinect and the two EDA and HRV signals, it generated a VFX particles

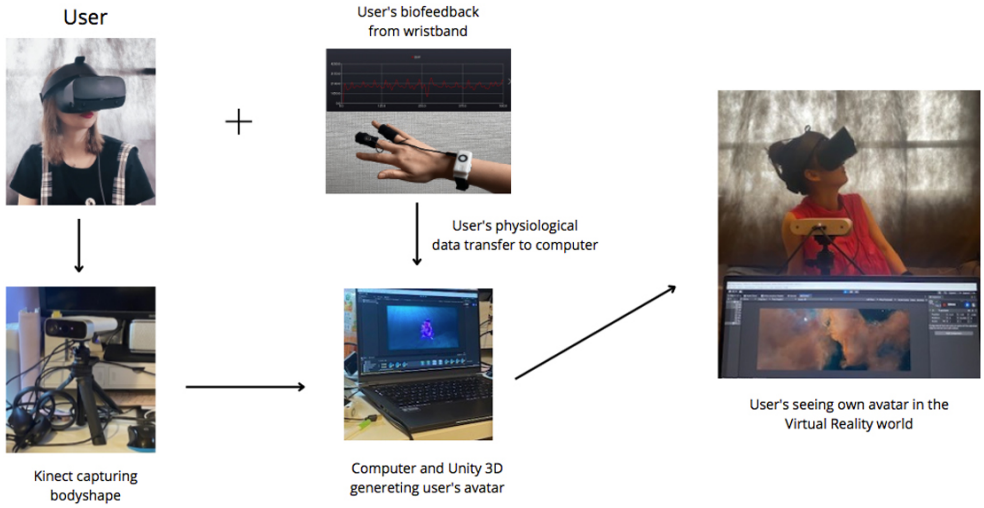

Figure 4.3 Experiment setup

system that responded to changes in the biofeedback data from the signal.

4.1.2 Participants

Thirteen people in the age range 18-44 took part in the experiment. The majority of participants (eight people) were in the 25-34 age range from different countries, including Poland, China, and Japan. In terms of gender, there were Males: 6 and Females: 7. All participants in the study had a communicative or fluent level of English. Participants came from various backgrounds, including students and former employees of companies that took part in the experiment.

4.1.3 Experimental Procedures

As mentioned above, thirteen participants were invited to participate in our prototype's usability test experiment. All participants had an individual experimental session. The user study was conducted indoors. To ensure intimacy, peace and a non-disturbing atmosphere, each of the thirteen participants had an individual session.
The following steps were conducted for the experimental session:

Figure 4.4 Experiment setup

1. Introduction and contest form

Foremost, participants were informed regarding their rights to participate in the research and that during the experiment, a computer screen capture would be in progress, and photographs would be taken; we described the investigation and procedures. After agreeing, they signed the contest form. Participants were also informed about the potential consequences of motion sickness caused by the VR headset and the opportunity to stop the experimentation at any time.

2. Pre-Survey

In the next stage, the participants answered a first self-report questionnaire regarding their stress level and emotional state; the Positive and Negative affect Schedule (PANAS) questionnaire consists of two ten-item scales to measure both positive and negative affect. This ranking includes various terms that represent feelings and emotions. The PANAS questionnaire intends to measure positive and negative affect and how an individual feels at the moment. Additionally, we asked a question about the age, gender, and emotional state during the last two weeks.

3. Preparation

After that, the VR experience commenced. First, we requested the participants to sit down comfortably and ask to put on the head Oculus Rift S VR headset. Then, to make the participant's Avatar bioresponsive, we place a sensing device based on ESP32 on the participant's left hand. Then we launched TouchDesigner and Unity 3D, and the experiment began.

4. Prototype experience

After the programs were launched and we confirmed that the participants were prepared, we began the experiment. First, they experienced an experimental condition leaning on the assigned order, which lasted 10 minutes. During this procedure, we log the changes in their heart rate (focusing on results indicating less stress level) and EDA (electrodermal activity to demonstrate lower stress and arousal of positive emotions). During the experiment, they saw three different avatar designs, high particle-points avatar, medium particle-squares avatar and

low particle-lines avatar responding to their emotional state in ten different backgrounds. During the investigation, we watched participants' gestures, reactions, and additional comments during the experiment.

5. Post-survey
After resting for 5 minutes, the participant filled post-survey questionnaire. We used the same PANAS survey as for the pre-survey. After the participants filled in the questionnaire, we discussed the experiment: feedback and interview from the participants.

6. Interview and Feedback
Finally, each participant was interviewed regarding their general feedback on the experience. After the experiment was completed, we conducted interviews with the participants. We discussed their avatar emotions, relaxation, and overall feeling. We also asked about additional comments, feedback, and how the system could be improved in the future to provide better experiences and relaxation.

After they experienced each condition, we collected and saved their physiological data (EDA and heart rate) and conducted questionnaires for analysis and interview with feedback. Once the experiment and whole procedures were completed, we proceeded to analyze the data obtained and split them into independent variants: questionnaire, discussion, and feedback. The results of our findings will be presented in the following sub-section of this work.

4.2. Result and Analysis

We tested thirteen people (7 females, 6 males, Aged 18-44) during the experiment. After each investigation, an extensive interview and PANAS questionnaire were conducted to understand better the experiment's outcome and impact on the user's emotions and the questions asked.

In the post-experiment questionnaire, we also asked questions about the effects of Avatar on relaxation processes, the impact on connection with one's emotions, and if experiments influence insight into the processes taking place inside our

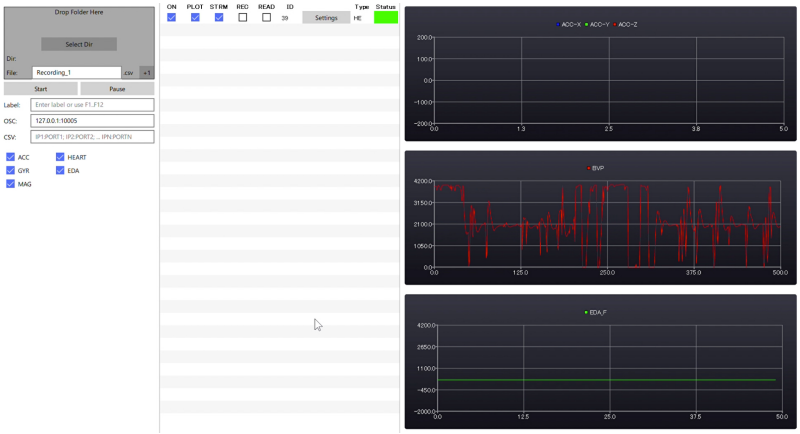

Figure 4.5 Data from sensing device based on ESP32

brain and bodies. Whether and how the proposed solution positively impacts their stress levels or their understanding of themselves.

4.2.1 Participants Responses from Survey

During the entire experimentation, twice PANAS questionnaires regarding user emotions were conducted - before and after the experiment. We compared the data from PANAS questionnaires to see how users' responses to well-being and well-being have changed.

We compared seven different data from pre and post survey: feeling nervous, anxious, stressed, alert, interested, inspired, excited, which were measured on a scale of 1 - Very slightly or not at all, 2 - A little, 3 - Moderately, 4 - Quite a bit, and 5 - Extremely. We compare emotions such as anxious, stressed, afraid, nervous, alert, excited. Each will be described and analyzed separately. Next, we will analyze the individual answers to the questions related to the avatar and the user's feelings. After analyzing the survey results, we will move on to discussing the observations and user comments.

Feeling nervous

In the case of the survey data on 'feeling nervous,' it can be seen that the overall

post-survey score shows a lesser sense of nervousness. In the pre-survey, one person chose 'Very slightly or not at all', nine chose 'A little', one person 'moderately', and two for 'quite a bit'. In the post-survey, seven people chose 'Very slightly or not at all ', five chose 'A little 'and one chose 'Extremely '. The user (P12), whose nervousness has deepened after the experiment, suffers from acrophobe, the fear of unknown places. It has been suggested that the participant should be able to choose the background for complete relaxation by themselves.

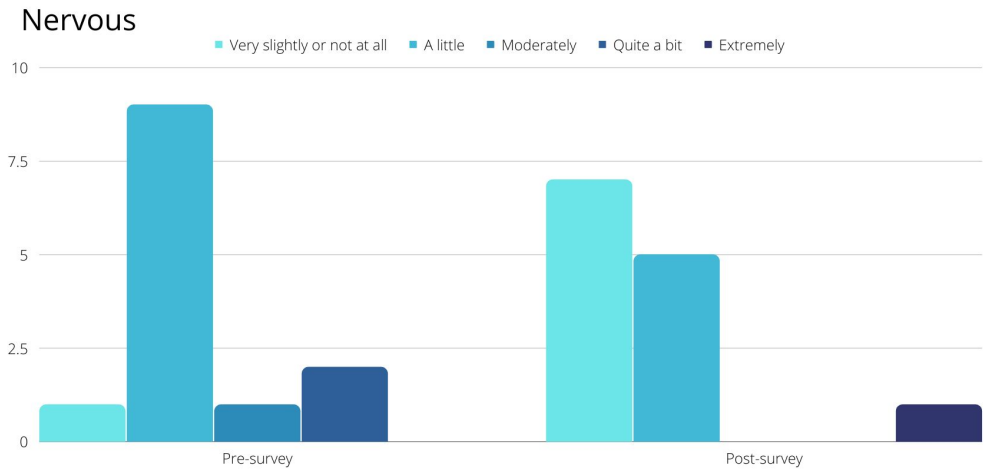

Figure 4.6 Pre and Post survey results; feeling nervous

Feeling anxious

In the 'feeling anxious' section of the pre-survey, the results are as follows: three people chose 'Very slightly or not at all', five 'A little bit', three 'Moderately', and two 'Quite a bit'. Compared to the results from the post-survey, six people said 'Very slightly or not at all', six 'A little', and one 'Quite a bit'. And in this case, the person whose anxious feeling did not change was the same participant (P12). In the general results for 'feeling anxious', we can see a reduction in anxious feelings among the participants can also be seen.

Feeling stressed

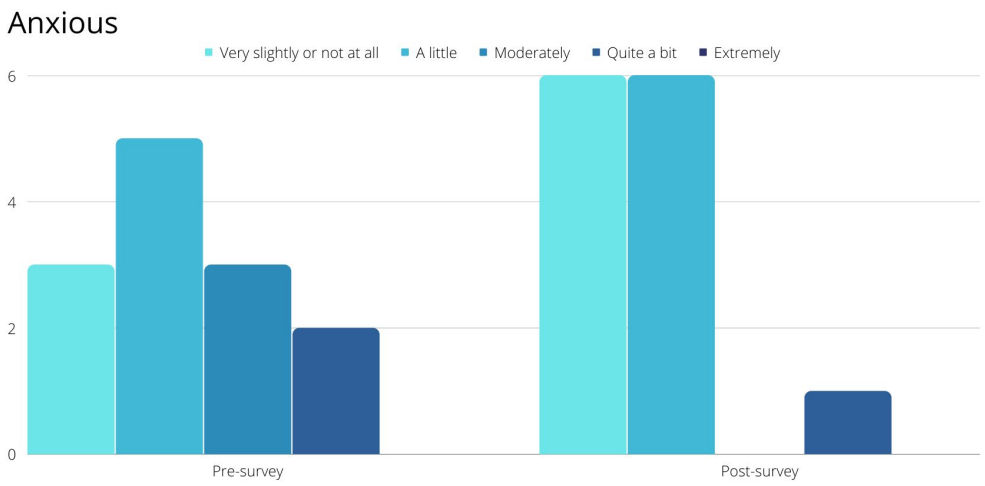

Figure 4.7 Pre and Post survey results; feeling anxious

Next, the results of the survey for general stress were compared. In this case, in the pre-survey, we have two 'Very slightly and not at all' people, seven 'A little' people, three 'Moderately' people and one 'Extremely' people. In the post-survey the results are as follows: eight people 'Very slightly and not at all', three people 'A little', one 'Moderately' and two 'Quite a bit'. So again, we can see a decline in overall stress levels in most cases.

Feeling alert

After an initial analysis of stressed, nervous and anxious survey data, they shifted to the 'feeling alert' analysis. Here we see results such as: four people chose 'Very slightly or not at all', five people chose 'A little' and four chose 'Moderately'. In the post-survey, the figures appear as follows: Eight people were for 'Very slightly or not at all', three for 'A little bit', one for 'Moderately', and one for 'Quite a bit'. In one person (P10), this state changed from 'A little' to 'Quite a bit' due to the duality between being 'sleepy' and 'excited' simultaneously, which the participant associated with adrenaline.

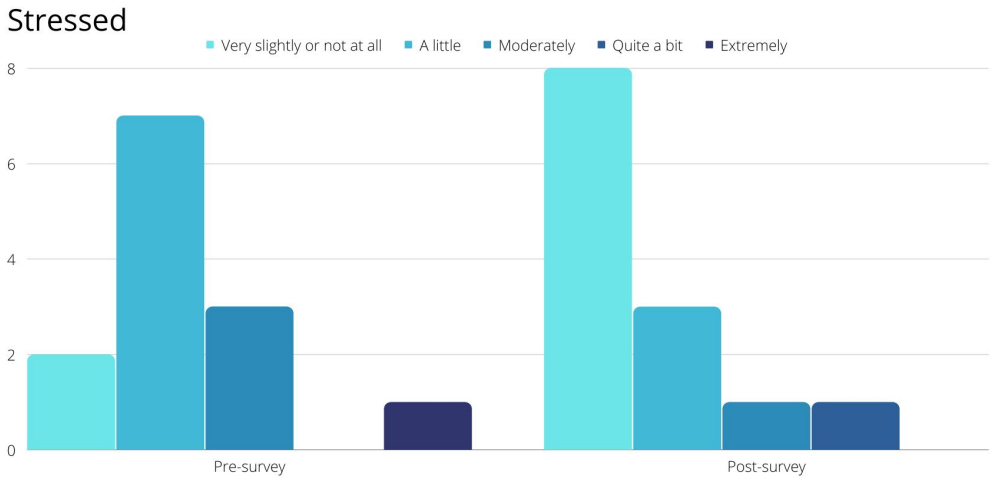

Figure 4.8 Pre and Post survey results; feeling stressed

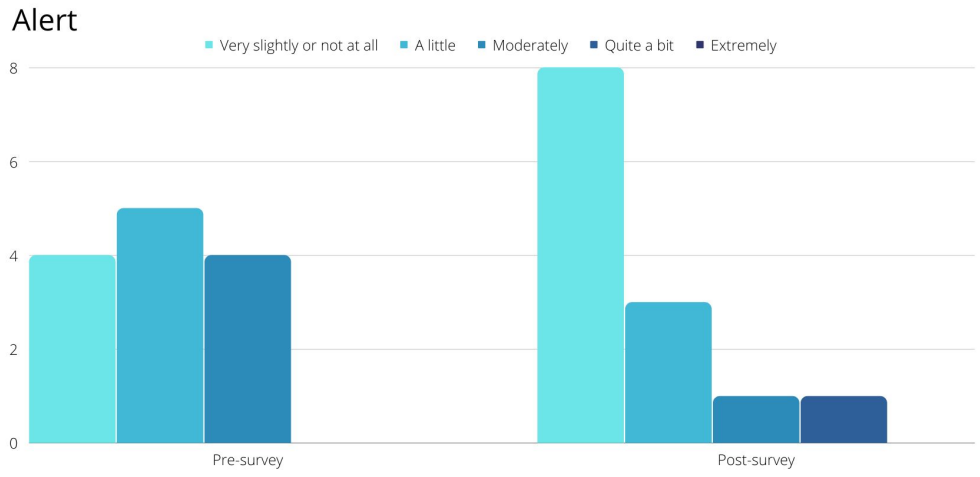

Figure 4.9 Pre and Post survey results; feeling alert

Feeling interested

We also compared the results of 'feeling interested' among the participants. Four people were 'A little' interested, bake 'Moderately', two 'Quite a bit', and two 'Extremaly'. In a post-experiment survey, three people were 'A little' interested, four were 'Moderately', three were 'Quite a bit' and three were 'Extremaly'. It can be noticed that the participants of the experiment have increased interest in the system.

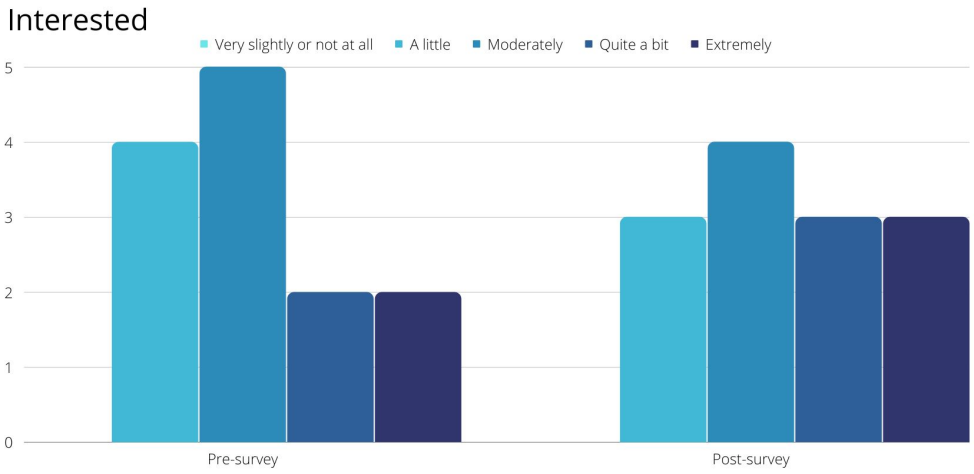

Figure 4.10 Pre and Post survey results; feeling interested

Feeling inspired

Another subject of the comparison is given to feeling inspired. In the first poll, three users voted for 'very slightly or not at all', three for 'A little', five for 'Moderately' and two for 'Quite a bit'. In the post-experiment survey, we have the following data: two people 'very slightly or not at all', three people 'A little', three people 'Moderately', four people 'Quite a bit', and one person 'Extremely'.

Feeling excited

The last diagram to be compared is 'feeling excited'. Seven chose 'A little', two 'Moderately', three 'Quite a bit' and one 'Extremely'. In a post-survey, the data

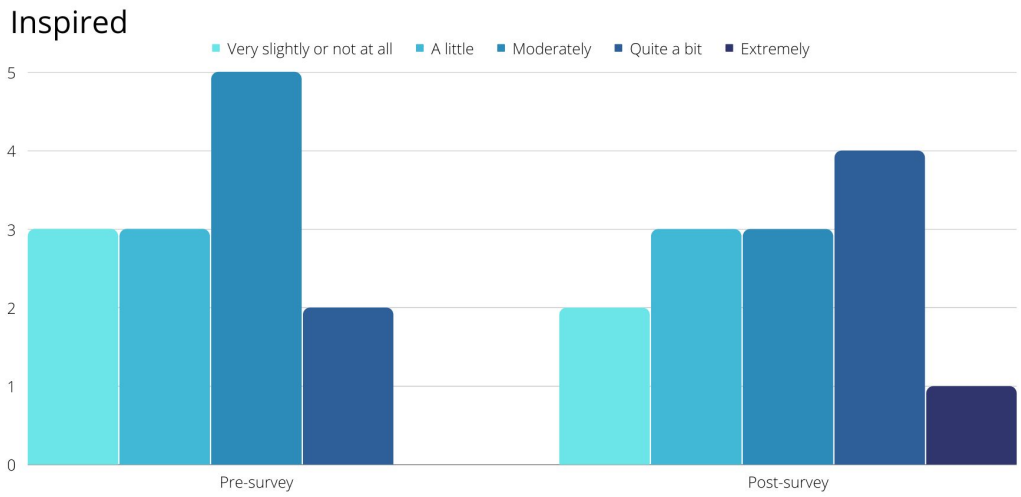

Figure 4.11 Pre and Post survey results; feeling inspired

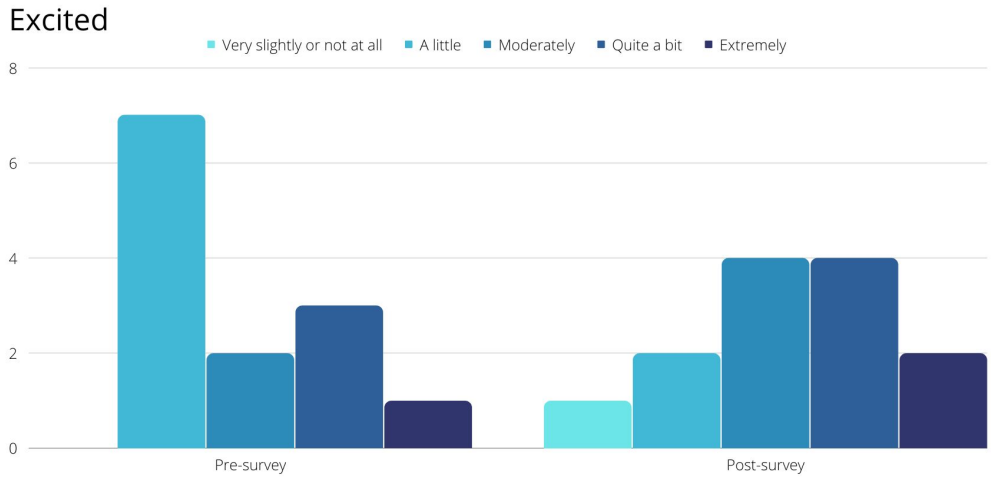

Figure 4.12 Pre and Post survey results; feeling excited

is one person ‘very slightly or not at all’, two people ‘A little’, four people ‘Moderately’ and ‘Quite a bit’ and one person ‘Extremely’. For this result, we can see a significant increase in excitement, with a one-person drop in excitement (P2).

Additional questions

In the next part of the post-survey, we asked questions about the avatar and emotions of the survey participant:

’I feel I can better understand my emotions’

and

’Seeing my own avatar made me feel more relaxed’

On a scale of 1 to 5, with one being the lowest value and five being the highest value. For example, after the experiment, two people rated their better understanding of emotions at 2, three people out of 3, six people out of 4, and two people rated their understanding of their emotions the highest out of 5. The results show up very prosperously for the second question about whether or not the avatar had a positive effect on relaxation. Four people rated the system at 3. Two people rated the system at 4, and seven ranked the avatar’s impact on relaxation at 5. Also, in the interview, the participants reported a positive influence of the avatar on ease stress, especially in the case of the high-particle point avatar.

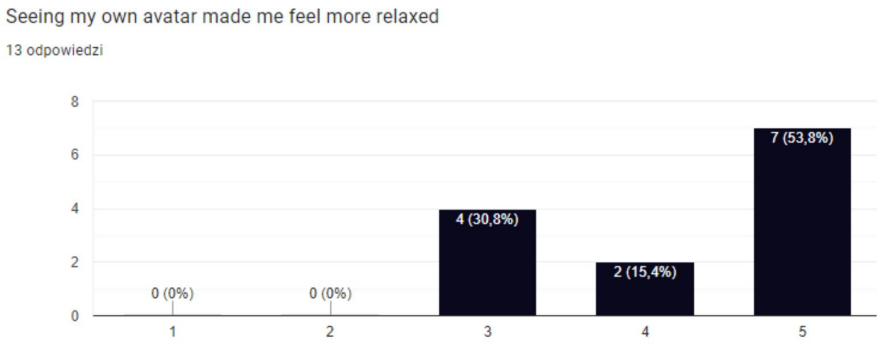

Figure 4.13 Survey results: seeing my own avatar made me feel more relaxed

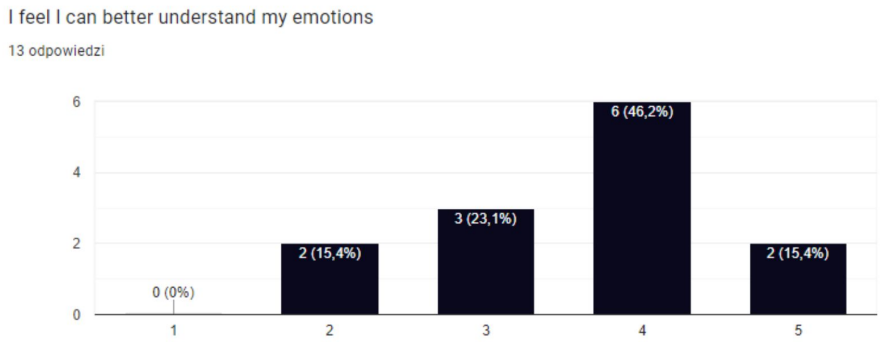

Figure 4.14 Survey results: I feel I can better understand my emotions

4.2.2 Comments and Feedback

In this section, we will present a table containing data from both of the surveys we have conducted previously. The table contains information on the thirteen participants identified from P1 to P13. Data about their gender, age, comments and feedback, and their avatar and background preferences. We will analyze comments and feedback from participants about the experiment. It will be discussed which avatar design influenced their relaxation best and was the most interesting. Additionally, background designs will also be discussed. Which had a positive effect on relaxation and the user liked the most.

Comments and Feedback part 1			
	P1	P2	P3
Gender	Female	Male	Male
Age Group	25-34	25-34	25-34
Comments	I feel Relaxed and bit sleepy.	I like particle, moving points inside avatar	Liked it and feel more relaxed
Feedback	It was very nice, I like aesthetic part of it. I can watch my avatar whole day, but VR helmet was a little bit too heavy. It could be nice as well to pick up own sound	More game-effects, like having swords and playing with myself will be cool	It was nice
Avatar design	Pink-blue particles	I liked particle effect	Particle
Background design	Pastel one and last one blue galaxy	small moon dark background	One with blue line and sun

Comments and Feedback part 2			
	P4	P5	P6
Gender	Female	Male	Male
Age Group	25-34	18-24	25-34
Comments	I feel more relaxed, calm and I like connection with my avatar, like seeing my emotions made me feel kinda better.	Vision design is really cool, somehow impact my mood	It felt fun at first, like traveling through the stars. Then listen to the music and start to relax slowly. Looking at my own image, I felt like I was in meditation.
Feedback	I feel more relaxed and it was very nice experiment, but it would be better if the avatar will be in "mirror" mood. I really like it, and it was nice to see my emotions	Yeah but I wanna watch something inside, maybe more animations, or something game related	I want can see some scenes of flowers and mountains and forests
Avatar design	Red and yellow one	Particles	Particle
Background design	Galaxy	Galaxy blue	All Galaxy

Comments and Feedback part 3			
	P7	P8	P9
Gender	Male	Female	Female
Age Group	25-34	25-34	18-24
Comments	Feel peace, comfortable and clam down	Relax	Calm down
Feedback	It really works when i saw my avatar in the VR environment. That is a unique and excellent design	Avatar is really good design	I really like the avatar design
Avatar design	Every	I liked particle effect	Particle effect
Background design	Interstellar	Sea	Sky

Comments and Feedback part 4		
	P10	P11
Gender	Male	Female
Age Group	18-24	18-24
Comments	It was very nice, I feel more relaxed and I feel a little bit excited to see my emotions and I feel a little bit sleepy but it is good	It works somehow
Feedback	It will be very funny to be able to travel around the galaxy with avatar or have more interaction with avatar	I did not feel the strong connection between me and avatar cos I realize it is just mirroring me. I hope the avatar could be some other characters rather than just myself
Avatar design	yeah kind of every is cool	Particle, but also last web was very nice
Background design	Pink clouds make me feel I'm flying and it was nice, but the most I like this silver black gold galaxy, very interesting and made me feel better, but a little bit sleepy	It really depends on the colour

Comments and Feedback part 5		
	P12	P13
Gender	Female	Female
Age Group	35-44	25-34
Comments	Some cases made me anxious but some made me relax	Like meditation, my brain got resting
Feedback	I feel relaxed with the environments i familiar with, but because i have an acrophobia, some pictures were quite scareing for me	Some scenes are similar, maybe can add some realistic scenes like streets or forest
Avatar design	Particle but long lines was as well nice	The digital one
Background design	Underwater	Green brown galaxy

Comments

Most participants commented the experiment was relaxing, aesthetically pleasing, and well-being. However, some users (P1 and P10) wrote that the experiment not only made them feel calmer but also made them sleepy. Two users (P6 and P13) compared the experiment to meditation. Also, as mentioned earlier, a critical comment was shared by P12 that some backgrounds made and felt anxious because of the phobia.

Feedback

After the experiment, the participants also shared feedback, which helped us sketch the research's future work. For example, P2 showed interest in a system that would also have the option to choose your music. With additional discussion,

it was added that choosing own soundtrack is essential to P2 because it could have a better effect on relaxation, as everyone has their own sound tastes. P2, P5, and P10 generally found the system exciting, but more interaction with the system would positively influence the desire to stay and enjoy longer. User P6 and P13 added that adding a background more like earth, like mountains, flowers, and forests, would be positive. Overall, the feedback received was related to possible interactions in the system, and the addition of a larger amount of background that will resemble elements of nature other than space and sky.

Avatar design

Users were introduced to three different avatar designs with ten different backgrounds. Most users reported that the high particle-points avatar is the most interesting and best for relaxing and understanding biofeedback. Users described the high particle-points avatar as a particle avatar.

Background design

Background preferences were much more complicated as most participants chose different ones depending on their preferred colors, feelings of relaxation, or mood. For example, P1 chose a pink sky because of a color preference. P2, on the other hand, preferred a dark sky with clouds and the moon as it was the most relaxing. During the interview, the P2 admitted that user liked the aesthetical background with the blue galaxy the most, but the moon was the most calming for him. P3's favorite background was the galaxy with a blue line and the sun, the same background that caused the P10 user to feel nervous and anxious. Most of the participants as well admitted, red sky background was disturbing.

4.2.3 Observation

During the experiment, we also conducted observations of users' behavior. Their gestures, verbal comments, how they moved, and what they focused their attention on. For example, P4, Female 25-34 yo made a lot of sounds of happiness or surprise during the experiment. During the investigation, P4 also commented on feeling more sleepy and relaxed after being in the environment for a long time. The participant looked around and tried to 'touch' the background. In contrast, P2, Male 25-34 yo sat quietly throughout the experiment, only observing his avatar. He slightly watched the background instead of focusing on the avatar's particles.

On the other hand, P5, Male 18-24 yo, and P10, Male 18-24 yo were much more moving around. During the experiment, both participants looked excited, and tried to interfere with the system and their avatar. The user P12, Female 35-44 yo with acrophobia was also interesting case to discuss. During the first backgrounds, the user behaved calmly. Still, in the case of 'unknown places', the participant reported a feeling of slight anxiety and asked to change the background to another because this (dark cosmos with an outline of a planet and a red sky that remained by P12 described as 'armageddon') was causing stress due to her phobia. Equally interesting was the user of P1, Female 25-34 yo, who tried to touch the avatar, interact with the system and manipulate particles inside avatar. This user was swinging his chair along with the music from the experiment. General users during the experiment showed interest in both background and avatar, but each user behaved slightly different inside the system.

4.3. Summary

Most users found the system relaxing, sometimes comparing it to meditation. The view of an avatar made of biofeedback for most users was an exciting experience that positively affected relaxation and self-awareness of how the emotional processes in their bodies look. We got a lot of positive feedback about the system as well as essential comments that can help us improve the system's performance in the future. So that it will be suitable for every user.

Figure 4.15 Final Prototype: Human-like (VR), interstellar background

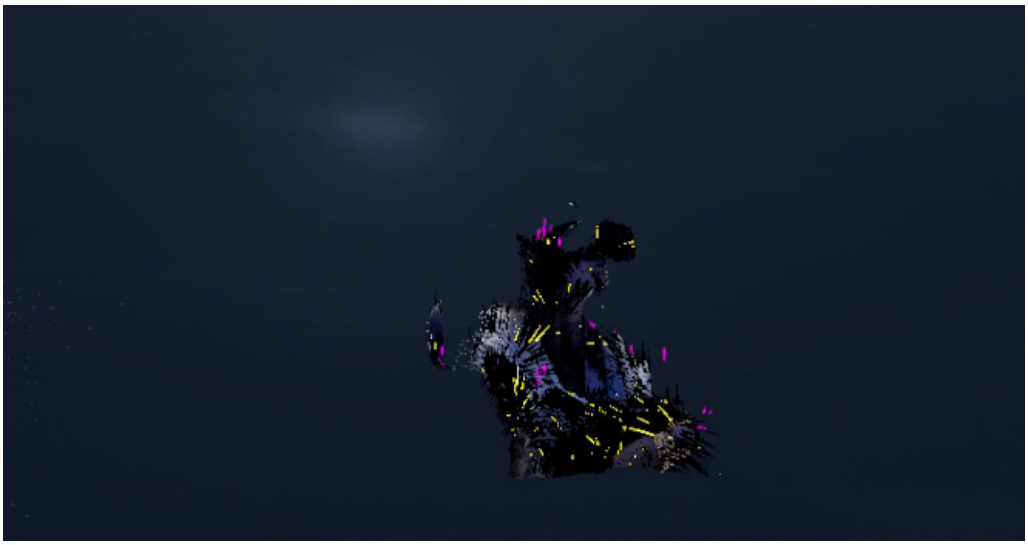

Figure 4.16 Final Prototype: Human-like (VR), medium particle-squares avatar

Chapter 5
Conclusion

5.1. Conclusions

As demonstrated in the foremost chapters of this thesis, the essential statement of research is to improve relaxation techniques and support stress relief by observing and interacting with a user's personification consisting of emotion-responsive particles in a Virtual Reality environment.

Current virtual reality-related studies seem to concentrate more on conventional meditation than on implementing different relaxation approaches, and self-avatar observation. Within the proposed work, we endeavor to obtain new practices, methods, and procedures for relaxation processes to relieve anxiety and stress from everyday life. Predominantly concentrated on avatars of the self that are bioresponsive; observations of user's physiological state, namely their heart rate and electrodermal activity, in the hopes that it can reduce the stress and anxiety. The system where the user can perceive the transformation based on biofeedback of particles in their self avatar and experience the difference in their avatar's appearance and presence. In the circumstance of relaxation, choosing to use a bioresponsive self-avatar seemed to influence participants' reception positively. Researching this field provides an opportunity for implementation that may be used for expanding VR relaxation techniques or, in some circumstances, be used in other areas and artistic projects. Due to increasing interest in the metaverse or Virtual Reality games, future applications of the Transcendental Avatar system may also develop into commercial projects.

The concerns of a stressed, overtired, nervous, and anxious society constitute a significant issue these days. A problem that can oftentimes conduct to serious health consequences and prevent standard functioning. Considering the essence of the problem and analyzing scientific works on VR, relaxation, and anxiety, we

discovered numerous findings which allowed us to determine the future of this investigation. In a related study, we found that with the usefulness of a VR system, it is achievable to construct a relaxation-friendly method that will allow the participants to calm down in an immersive and engaging way. Scientific work in the specialization of Virtual Reality and applications of this procedure in medicine and well-being is continuously being developed and researched on numerous levels. Clarifying the positive effects of VR applications in the context of relaxation, stress, and anxiety demands more research and addressing various connected topics.
According to the outcomes of the studies described in Chapter 4, it seems experiments and an interview that was carried out to verify the hypothesis had a positive influence on relaxation processes. Overall, the Transcendental Avatar system does provide relaxation and ease stress for individuals. However, still our prototype left an open way to develop more possibilities of using self-avatar for relaxation techniques.

5.2. Limitations

There are a few challenges that need to be addressed. The research was conducted on a random and diverse group of people and showed the effect of the system on relaxation at the moment. However, to make the findings more precise, the experiment should also be conducted on a group of recipients who are currently experiencing stress or anxiety. In addition, studies should be performed on a specific group of users over an extended period to determine whether the proposed solution can affect overall stress and anxiety or whether it only works to relax temporarily.
Additional research should be conducted on a specific group of users, such as people with anxiety disorder, people exposed to prolonged stress, or someone with depression. For this, cooperation with medical institutes is essential. On the other hand, it is essential before additional study to improve the system based on the interview, observations, and user comments.
In a general summary of the comments, it is necessary to:

- Introduce more ability to interact with the system - some users reported that

the ability to interact with the design, both with the avatar and background elements, would positively affect the perception of the program and the feeling of having more control over the site, and thus improve stress-relieving processes.

- The user's ability to choose the appropriate background and soundtrack - some of the study participants reported that some of the scenes used in the prototype were disturbing and stressful. However, they had a relaxing effect on others. In addition, the inability to choose a soundtrack that matched the participant's current mood proved to be a significant limitation in terms of relaxation and well-being.

Also, the Virtual Reality technology currently available on the market is an essential limit for the system. In terms of the long-time use, the Virtual Reality headset caused some users to feel nauseous after staying in the program for a while, and also, after taking off the device, it took a few minutes for perception to sharpen to the real world. In addition, the VR headset has a slight chance of causing motion sickness while in Virtual Reality.
The second downside of the Oculus Rift S VR headset we chose is that the device is heavy and can cause neck pain with prolonged use. In the case of the experiment, the user sat in a comfortable position, but if more interaction with the system is added, it will be important to select a headset that is lighter and more comfortable.

5.3. Future Work

There are several likely directions in which future work can be carried out to improve the above-described system. Initial plans for strengthening the system were influenced by the study's results, comments from participants, our contemplation about the experiment, participants' perceptions of the investigation, and participants' reactions during the experiment.
Firstly, the current work can be further developed to improve the system of more interactions and relaxation methods. For instance, it has been discovered that some users feel stressed about particular backgrounds. Considering this factor, it

is essential in future work to allow the user's to select an appropriate and comfortable environment that will enable more accurate relaxation processes and reduce stress factors better. In addition, after analyzing the results of the experiment as well as the comments received from participants, we decided improvement of the next version of the prototype. We would like to focus on increasing interaction with the system by allowing participants to perform specific actions such as the capability, as mentioned earlier, to choose the appropriate background and select the soundtrack or sound effects, as well as, in the beginning, limited ability to move around the world and touch particles unrelated to the avatar.
We believe such improvements can help people be more accessible, better maintain healthy mental states, and assist in faster recovery from stress and anxiety.
Secondly, in the distant future, we are also considering making changes to the user's avatar and implementing an Avatar AI system that can move in a limited way independently and respond or react to changes in the user's emotional state.
Additionally, since the sample size for this study is small, more data from participants of different age groups, gender, and ethnic background will be needed. We will conduct more user tests to do this in the near future. In order to gather more accurate data, we would like to improve the detection methods by including breathing measurement devices such as breathing sensors and thoracic or diaphragmatic respiration sensors in our user study.
Therefore, creating a more prosperous and efficient system in the future requires more collaboration with other researchers from virtual reality avatar or physiology backgrounds. It is also under consideration to conduct future studies on specific audiences in cooperation with medical institutions. We are considering focusing primarily on individuals exposed to prolonged stress, anxiety disorder, depression disorder, ADHD, or autism.
As mentioned earlier, the concept of "Transcendental Avatar" opens up an interesting issue related to the presence of one's avatar, personification in relaxation processes. Future investigations will help us better understand and improve the system and create a more precise concept.

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