Listen to your body signals in immersive virtual reality.

A virtual reality relaxation environment in combination with biofeedback for the use of therapy and rehabilitation for patients with chronic back pain.

Graduation Project
Creative Technology
Yasmin Salce
S1530828
06/07/2018

Supervisor: Miriam Cabrita
Critical Observer: Alma Schaafstal

Abstract

Chronic pain is pain that lasts longer than three months and it can arise from injury, this affects millions of people worldwide. Roessingh Research and Development (RRD) have developed the Virep project which is a virtual reality game to improve the training of chronic pain both in clinical and home settings. This graduation project will develop an extension of the Virep project by creating a virtual reality relaxation environment. This project will go through some iterative design testing in order to find the best result of creating a relaxation environment. The final relaxation environment was created so that the users biosignals would be mimicked in the environment. The goal is so that the user had to listen to their own bodies and the virtual reality world in order to decrease their heart rate. The final environment proved to achieve the goal of relaxation but testing needs to be continued on people who have chronic back pain.

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Chapter 1: Introduction

1.1 Situation

The use of virtual reality in the healthcare department is becoming more and more popular as new technologies are getting developed. The advantage and appeal of technology for healthcare is that it can easily be customized to fit the unique and specific needs of the patients. Within this field, virtual reality has been used for teaching medical professionals and in rehabilitation. Virtual rehabilitation is the combination of using virtual reality for the use of rehabilitating patients, there are many kinds of virtual rehabilitation, but for this case it will be used for therapy with patients with chronic pain. Chronic pain is pain that lasts longer than three months and it can arise from an injury, such as a back sprain or come from an ongoing cause such as an illness[1].

Roessingh Research and Development (RRD) is a research and development enterprise that focus on rehabilitation technology and telemedicine with strong links to one of the largest rehabilitation centers in the Netherlands (Roessingh Rehabilitation Center) and the University of Twente. RRD have been exploring the development of using virtual reality training to help patients with chronic pain. Currently they have developed and are testing their Virep project which uses a “virtual reality game to improve the training of chronic pain both in the clinical and home settings.” They created this with heavy collaboration with therapists and patients so that it will be able to meet to the specific needs of their patients. The company Salt and Pepper have been used to create the virtual reality game simulation.

1.2 Challenge

Within the Virep virtual reality game there is also a relaxation environment that the users can go to to relax. It has not been fully developed so the aim of the project is to extend the Virep project by creating, developing and building a virtual reality relaxation environment for the use of therapy, specifically for patients with chronic back pain. The patient should be able to rely on the environment to help them relax, such as the surroundings could move in such a manner that it helps them with their breathing exercises, eg waves moving. It is important to include and incorporate the users biofeedback. Their biosignals will be monitored and used as feedback during the environment, this will allow then to listen to their bodies and respond accordingly. Since the patient only has limited time in the environment it has be easy clear to what the user must do in it. Such as the relaxation techniques that they will perform also need to be quick and easy to use. The aim is to create an environment that they can successfully relax in with not so much effort on their end. The environment should accommodate them and lead them to a relaxed state.

1.3 Research Questions

In order to create a virtual reality relaxation environment that incorporate biofeedback, there are several things that need to be investigated in this project. The goal of the state of the art is to find out which relaxation techniques will be the most useful in a virtual reality setting. Therefore the research question throughout this project will be:

> "To what extent was the relaxation environment successful?"

To achieve this several sub questions also need to be answered. Collectively they will provide an answer to the main research question.

- How effective can breathing be used in order to aid a virtual relaxation environment for patients with chronic pain?
- How will the users biofeedback encourage them to listen to their bodies and adapt accordingly?

Chapter 2: State of the art:

The implementation of relaxation techniques in virtual reality for the use of chronic pain management and therapy.

Virtual reality is becoming increasingly popular and has many uses for its application in healthcare and in gaming. Virtual reality in healthcare is becoming more apparent as medical professionals are able to perform surgical training and behavioural treatments[2]. Virtual reality can overcome the limits of traditional rehabilitation, as it can simulate environments beyond what is possible in the real world and be tailored to the specific needs of the patient. For this case virtual reality will aim to help patients with chronic pain through the use of a relaxation environment, this will be done for the Roessingh Research and Development department as part of a graduation project. Therefore the factors that contribute to a beneficial virtual relaxation environment for patients with back pain need to be investigated. This will be done in combination with their biosignals, so that the user can listen to their body and respond accordingly.

In order to create to virtual reality relaxation environment, various relaxation techniques must be found and investigated. The goal of the literature review is to get insight into how virtual reality can be used for health care and also the most useful kind of relaxation technique for a relaxation environment. The most effective techniques will be analysed through the literature research so that it can be known which one will can be implemented into the virtual reality environment. The relaxation techniques that will be analysed are: music therapy, guided imagery, breathing, mindfulness, progressive muscle relaxation and dialectical behavioral therapy (DBT).

2.1 Relaxation for the use of Pain Management

There are many ways for patients to manage pain, but for this particular case it will be found how relaxation can be used for pain management. Such as when the body is in a stressful state it causes the muscles to tense and tighten, which will cause an increase of pressure on the nerves and other parts of the body, and therefore can cause the feeling of pain to worsen[3]. Relaxation techniques have proven to aid in pain management as it reduces stress and muscle tension, which will in fact benefit the whole body[4]. Being able to distract the body from the pain has proven helpful with pain management, because patients who do the exercises are more able tolerate the pain[5]. [6] found that there is strong evidence for the use of relaxation techniques in reducing chronic pain. Chronic pain is defined as pain that lasts longer than three months and have a negative impact in the daily lives of the individual. [7] agrees with [6] evidence because they conducted a critical appraisal for 10 studies about relaxation and chronic pain and found that three of the studies reported a decrease in pain as a result of the relaxation intervention techniques, and found that one study showed an improvement in health-related quality of life. Although relaxation techniques may be helpful, it is possible that patients who

experience severe pain may not have the concentration to try a new technique until their pain is managed. This is why the relaxation techniques must be easy to learn and easy to apply in order to benefit the patient.

2.2 Relaxation Techniques for Chronic Pain Management

Relaxation techniques can be used in order to manage chronic pain, the relaxation techniques that will be analysed are: music, guided imagery, colors, breathing, mindfulness, muscle relaxation and dialectical behaviour therapy. These techniques are a psychological intervention that aim to help improve the well-being of the patient. There are many relaxation techniques that could be used but they mostly have the same things in common which can be seen in Table 1. In order to find out which techniques works the best it has to be able to produce the body's natural relaxation response which can be seen by slower breathing, slower heart rate and lower blood pressure[8]. Therefore the techniques that can accomplish this the most efficiently will be the most useful one. All the techniques mentioned will be briefly explained and explored.

Table 1 - Relaxation factors[9]

Relaxation Factor	Reasoning
a mental device	a constant stimulus on which the patient focuses, such as slow deep breathing, a repeated word or phrase, or a spot on the wall
a passive attitude	which involves ignoring distractions while maintaining focus on the mental device
decreased muscle tone	which can be detected by observing the patient (the jaw should be unclenched, the shoulders not hunched, and the hands not fisted) or by asking if the muscles feel relaxed
a quiet environment	one with minimal distracting stimuli, enhances the patient’s attention to the mental device

Music therapy has been used for pain management for patients with chronic and life threatening illnesses by decreasing the patients pain and suffering[10]. Music therapy can do this by distracting the body's cognitive and sensory stimuli through the use of euphonious sound, which can help to alleviate some of the pain. Research by [11] has shown and proven that music therapy has the ability to decrease pain and anxiety in critical care patients. This shows that music therapy is a useful and easy way to relax users.

Guided imagery is a relaxation method where the patient concentrates and thinks about positive images in order to decrease pain and other stressful factors. Guided imagery and the use of aesthetically pleasing colors is another relaxation technique that can be used for pain

management. This is because visual and imagery processes can “help calm, soothe, relax and enhance images of harmony and wellbeing”[12]. Guided imagery and colors are also another beneficial way to treat patients and reduce their stress in order to help them relax.

Breathing techniques is also another method for relaxation as it will allow the patient to control their breath and lower their heart rate. There is a techniques where the patients can use a deep belly breathing techniques that synchronises breathing with their rate which will create sinus arrhythmia, which means that they will be in a state where they cannot feel anxiety[13].

Mindfulness is a technique that has been used a lot when dealing with chronic pain. It combines meditation and yoga and training of awareness which reduces the stress of a patient and therefore lowers the perception of their pain. This intervention has also showed consistent success in the treatment of several chronic pain disorders. [14] To practice mindfulness the patient has to see their emotions, thoughts and feelings are neither good nor bad but as something that they are aware of and can accept. It has been concluded that when the persons acceptance increases then there is a decrease in the stress and struggle to control the uncontrollable[15]. [16] have also concluded their article saying that there is large evidence that shows that mindfulness has the ability to change the brain's cortical structure that may modulate pain and improve emotions. This further agrees with [17] as they also found that through this, patients significantly improve self efficacy and found that this technique is associated with improved emotion regulation and thus better health outcomes. Meaning that this is the perfect technique that can be used for relaxation.

Muscle relaxation is also a relaxation technique that can be used, but it is also an outcome of the other relaxation techniques. Such as, all the other techniques create a less stressful feeling for the patient so that their bodys relax. Therefore instead of being a technique it should be an outcome, but progressive muscle relaxation is a method based on the fact that “muscle tension is the body’s psychological response to anxiety-provoking thoughts and that muscle relaxation blocks anxiety[18].” It is mentioned here because it is a relevant technique that can be taken into account.

Dialectical Behavioral Therapy (DBT) focuses on emotion regulation through the use of various techniques. It has 4 aspects to it which are: mindfulness, distress tolerance, interpersonal effectiveness and emotion regulation[19]. DBT is a balance of acceptance and change strategies, which is where the term dialectical comes from. The most important one here is DBT mindfulness. It can have the ability to regulate emotions, tolerate distress and negative emotions[20]. DBT is a form of cognitive behavioral therapy and a literature review was carried out on chronic pain and CBT and they found that in the 35 studies that were reviewed the results were that CBT reduced pain intensity in 43% of them[21].

2.3 Biofeedback

In order to see whether the patient has successfully learned how to relax, their biosignals will be taken into account, these would be their heart rate, breath rate and blood pressure. Biofeedback is used in order to help aid the patient understand their bodies and to gain control of it, such as manipulating your breathing to overcome a stress and anxiety. Monitoring these signals will make it clear how calm or stressed the patient is as it “facilitates learning by giving precise,

immediate information about muscle tension, heart rate[22] ” and any other parts of the body that are being measured. This affirms [13] as they use biofeedback to make patients aware of their reaction during their virtual reality experience and teaches them how to control their bodies.

2.4 Virtual Reality in Healthcare

The use of virtual reality technology continues to grow in the healthcare sector especially in the areas of rehabilitation and therapy. It has resulted in encouraging results being reported for applications that address human physical, cognitive, and psychological functioning[23]. Virtual reality is a 3-dimensional computer generated environment that the user can interact with and explore [21], [24], it makes the user feel like they are actually in the virtual environment that has been created.

2.4.1 Virtual Reality for the use of Rehabilitation

Virtual reality for rehabilitation is a new form of treating patients as it is a power tool for rehabilitation, as it offers unprecedented potential[25]. It has the ability to provide motivating training that can be superior to traditional training, which has resulted in an increase efficiency and advancement for the patient[26]. Virtual reality has the ability to put the patient into different testing environment, so that it can be utilized for various aspects of rehabilitation. The advantage is that is allows the user to change the testing parameters and explore tasks that may be unsafe in the real world, since a full virtual reality environment can mimic the real world[27]. Compared to traditional rehab VR has the capabilities to also measure and give feedback to the patient and is customizable per patient[27]. Virtual reality based rehabilitation is an exciting and emerging technology coming from this field. [28] have concluded that VR can be recommended as a clinical intervention for pain management, at least for acute pain. It is an effective pain relief for patients with chronic pain as the VR environment will distract their attention from the pain.

2.4.2 Existing VR technologies for relaxation

Currently there are some VR applications that teach you about mindfulness and relaxation, these existing technologies will be analysed, they are Guided Meditation VR, Lumen and Perfect. Guided Meditation VR is a relaxation app where the user can recharge in various locations across the universe. It is an application where you can customize a virtual guided meditation to fit the needs of the user, and acts like a personal trainer for the user. This app allows the user to explore 20 different surroundings to find a place to relax and user their 9 guided mindfulness lessons, Image 1 shows the kinds of selections that can be made in the application. The application include biofeedback and are the world's first VR app to measure heart rate in VR without any add-ons, they use this to show the user the “calming effects of meditation in person![29]” However it is unclear and not mentioned anywhere how they

incorporated biofeedback in their application because current VR headsets do not have a built in heart monitor.

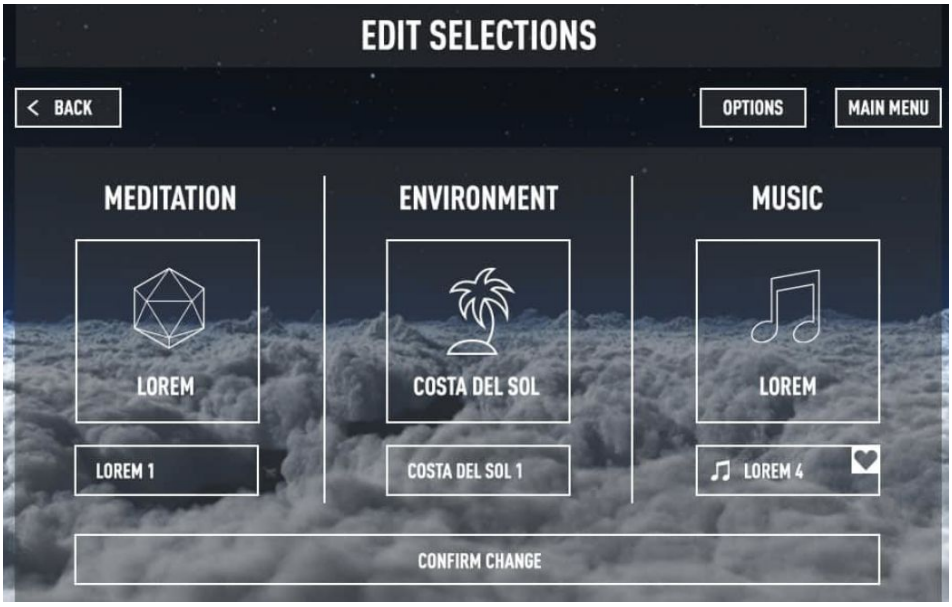


Image 1: Guided Meditation VR selections

Perfect is a virtual reality application that allows the user to relax in a beach environment, it contains guided meditation and tranquil music. They can choose from 2 beach locations which are a sunny day or a sunset. The aim of the application is to help the user relax through meditation or exploring the environment[30]. Lumen is the other virtual reality relaxation application. The viewers gaze dictates the environment, this is done by making the tree in the environment grow or sprout when they look at it for a period of time. It is meant to help the user meditate and focus on a particular space.[31]

2.4.3 Virtual Reality studies:

Several studies have been on the effect of virtual reality with rehabilitation and relaxation, these studies will briefly be explained. A study was conducted where meditation experts try VR mindfulness applications, the goal of the study was to find out the feasibility of VR to facilitate the mindfulness practice and whether they would show any benefit. They used VR DBT®(Dialectical Behavioral Therapy) mindfulness skills training. It was found that after VR the participants reported that they felt less sadness, anger and anxiety and actually felt more relaxed. The 40 participants also showed that VR was indeed feasible and acceptable a technique to practice mindfulness[32]. This VR application was also used in a another study where they used this system to help a burn patient who had developed negative emotions because of it. After using the system the patient reported a decrease in negative emotions and an increase in positive emotions, it also showed that the use of VR enhanced the DBT training with this patient[33]. There was also a study that investigated the effectiveness of an underwater world for relaxation. They combined an underwater world relaxation environment and

incorporated breathing techniques in order to reduce the stress of the patient. They found that the VR world was more effective and fun and more likely to be used than traditional techniques[34]. This shows that VR has proven useful in aiding patients with their therapy, although it is unclear which VR applications that they have used so further research in those applications must be done.

2.5 Conclusion

Based on the literature research done it can be concluded that virtual reality can help aid the use of pain management. Although the relaxation studies with virtual reality proved beneficial for the patients, it lacked information to what the patients were actually being exposed to or the applications that they were using. This meant that further research into those applications could not be done. Virtual reality for the use of pain management is still quite a new concept, so there are not many papers or studies available on this topic. So this is only a small selection of work and perhaps in the future there will be more knowledge and studies on this. Nonetheless, the goal is to build upon and explore what has been done in the past by adding various relaxation methods and make it applicable for patients with chronic pain. From the relaxation techniques the best ones to include would be DBT mindfulness, which makes the patient observe sounds and visuals and breathing. In order to create a relaxation environment that can help the patient their biofeedback must also be incorporated, as it can help the patient control their breath or heart rate. Further research must be done on the relaxation techniques because now it has been found how useful they are but it needs to made clear how to execute these techniques, or which of the many DBT mindfulness or breathing techniques must be used.

The eventual product that is being created will be a multidisciplinary pain management relaxation virtual reality environment with biofeedback incorporated into it. It will include breathing as the main technique for relaxation, but be accompanied with the sounds and visuals most suited for a relaxing environment.

Chapter 3: Research Approach

For the research question to be successfully answered, a research approach and method needs to be established. The research approach gives structure to creating the project and answering the question in a systematic way. The phases of this are: ideation, specification, realization and finally the evaluation. The Specification, Realisation, Usability testing and Realistion sections will be done per testing phase of the project, since these phases rely on the results of the previous stage. The three phases it will be split up into are: Chapter 5: Breathing Environment, Chapter 6: Visuals Environment and Chapter 7: Biofeedback.

3.1 Ideation

The Ideation phase is where the possible ideas for the project are created and explored. At the end of the Chapter 2 in this report several aspects will be chosen to be integrated into the relaxation environment. It is known what needs to be incorporated, therefore the Ideation phase will help make it clear how this can be done. By the end of this phase, the best implementation method will need to be chosen and then created in the Realisation phase. As there are many ways to execute the project, this project will deal with iterative testing, where testing will be taken place weekly so that constant improvements can be made.

3.2 Specification

The specification is the description of the objects and development of this project. It will contain everything that the project needs to develop to reach its desired outcome. It will contain the goals, functionality and details on how to proceed. Within all the environments that will be created the user should be able to walk around and explore the whole environment. In order to not make it overwhelming for the user the area they can cover will be approximately the same size of the area they are in in the real world, the area will be 2m x 2m.

3.3 Realisation

The realisation phase will implement the ideas that were created in the ideation phase. This can only be done once it has been made clear what needs to go into the project. The realisation of the project will be conducted in three phases. Along the way, each step will be tested along the way so that the best outcome can be continued with. The next phases will just add on to the environment that has already been created. This phase will include the method of implementation and of the project. The method will decide in which order the characteristics of the environment will be implemented. It will also explain how Unity was used and what other assets were used in order to create the final project.
This chapter explains how each part of the prototype will be created, the first phase in implementing an environment that facilitates breathing, the next step is to test to what extent will

the crowdedness of the environment lessen relaxation and cause stress and the last part is to integrate the users biosignals so that active feedback can be given while they are in virtual reality.

3.4 Usability testing

Each phase of the project will be tested so that design alterations and improvements can be made for the final outcome. The test format will describe how the tests should be taken. The first test will test 3 different environments regarding how the environment can influence breathing. The second test will determine to what extent a crowded environment will calm or stress out the user and the third test will find out if mimicking the users biosignals or not will aid in them in relaxing.

3.4.1 Testing protocol/method

In order for the testing to run smoothly a test protocol must be made to make sure everything goes as planned. Three tests will be conducted and they will all have a goal and a description for how it should be carried out and then finally it will end with a quick survey about what they have experienced while testing the project. The goal of the iterative testing to to find out which direction the design should go, this means that several hypothesis will be tested to determine this.

3.4.2 Test Format

This will be the basic same testing format for all the phases. The testing will be done at either the Roessingh Research and Development facility or at the University of Twente. The user will sign a consent form that will allow us to analyse their data and record them, this form can be seen in the Appendix 2. Approximately five to ten people will be involved with each of the tests and there is no defined target group for the iterative testing phase. The final project will be tested with a clearly defined target group and with over 10 participants. Each test will last around five minutes because the goal of this testing is to let the user experience each environment and give their feedback on it. After every test the user must take a survey answering several questions regarding the environments, these surveys will differ depending on the phase. The various surveys for each phase can be found in in the chapters that carry out the testing so 5, 6 and 7.

3.4 Evaluation/Results

The evaluation phase is where the different iterations and the final prototype are tested and once everything has been implemented the environment needs to be measured so that conclusive answers can be found to the research question. The results will be split into the three phases that have been mentioned multiple times in this report. Each phase requires a different test, so they will be evaluated separately.

Chapter 4: Ideation

4.1 Ideas

Everything in the virtual environment must be easy and quick to use because the patient will not have a lot of time in there. Therefore the environment has to be suitably made to achieve relaxation in an efficient way. The implementation needs to meet several requirements, they are: relaxation techniques that are easy and quick to use, biofeedback that should aid the user, biosignals that are measurable and lastly everything in the environment should work together to relax the user.

4.1.1 Relaxation

To help the user breathe at a pace that should relax them, the environment should move in such a way so that the user can look to it for guidance. Such as, waves moving back and forth to represent the breathing pace, or the sky pulsating at this same pace. According to JunoVR[1] breathing should be timed at a rate that leads to long slow cycles which are correlated with deep relaxation. This means that the time needed for inhaling and exhaling is 4 seconds.
Since there are several ideas for this case, they will all be tested and the best one will be chosen and then the next phase in the programming can begin.

4.1.2 Visuals

Users can feel bored if there is nothing to do or interact with within an environment. The point of the changing visuals is to see if the users have enough objects to look and if they would feel more relaxed than bored.
The point of this is to create objects in the environment that feel natural. The environment will range from an empty space to one filled with various objects. Various stages of clutterdness or emptiness of the environment will be tested to see which one will be the best to implement into the final product. There has to be a limit to how cluttered the environment can be because it can start to become distracting instead of relaxing.

4.1.1 Biofeedback

The biosignals will consist of a heart rate and a breath rate. The aim is to make the environment change depending on this feedback. Two different hypothesis will need to be tested here, the first one is if the environment should mimic the users biosignals, which means that if they have a high heart rate then the environment will also act crazy and will only calm down when they calm down. The second hypothesis is that the environment should stay calm and help the

[1] http://junovr.com

patient become relaxed this way. The user can influence their surroundings from both hypothesis'. It needs to be determined which one is more efficient for relaxation.

4.1.4 Measurement

In order to find out the answer to the main research question, of "To what extent was the relaxation environment successful?", some key elements need to be measured. A relaxed person has a heart rate of around 60-100 beats per minute(bpm). The users heart rate will need to be taken before and after they have experienced the relaxation environment to see if there are any differences. A graph can also display their biofeedback throughout the testing and see how it can be affected by the different stimuli in the environment. A test can be conducted on how the different aspects of the environment can affect the user, such as the breathing techniques and interactions.
The environment will be tested constantly because of its iterative design, therefore improvements can be made based on the users feedback. Since the goal is to measure how relaxed the person is, if the pilot testers are already relaxed then the testing would not be accurate. Therefore a stressful situation needs to be simulated with the tester first so that they have the possibility to be able to lower their heart rate during their VR experience.

4.2 Design Choices

The final design choices will be explained here. There are several ideas for the things that need to be implemented into the environment, this project will have an iterative testing approach. This is where constant testing is done so that continuous improvements can be made. This will also help rule out ideas that will not be beneficial to helping the user relax in the environment.

Table 1: Pros and cons of design decisions

Design	Pros	Cons
Environment that facilitates breathing - Waves moving back and forth - Clouds/object pulsating - Trees moving in the wind	Helps the user to breathe at a certain rate. Testing all of them will lead to the best option to implement in the end	Requires testing for the three ways of doing it.
Showing the breath as the user breathes out	It will add some realism to the environment because they can see the outcome of their breaths.	Could be distracting. Might be difficult to implement since it has to work with the breath rate sensor.
Environment mimics	It will make them feel like they	It might stress out the user

biosignals	are in control when they are able to calm themselves, because they can see it happening in the environment.	even more if they environment is going crazy when they have a higher rate rate
Environment stays steady to calm the user	There is nothing there to stress them out more	It can become boring
Pulsating Object	Allows the user to focus on one specific object out of many	distraction
Environment that mimic biosignals	The user will be able to feel like they can control anything that happens in the environment.	It stress/scare the user

There will be three different kinds of environments that will help the user breathe at a certain rate. All the environments will be accompanied with sounds or music that relates to the scenario and will aid in the relaxation of the user.

4.2.1 Environment that facilitates breathing

The goal of these different environments that accomplish the same thing is to find out which one is received the best by the users. There are three ways in which it can be done and this is further explained below.

4.2.1.1 Waves

In the first environment the user will be surrounded by the ocean where they only have little room to walk in. The waves will come in and out at the pace in which the user has to breathe. Image 2 shows that when the user sees the waves coming in the they should inhale and when the waves retreat they should exhale, or vice-versa. The waves should be large enough that it is clear what the user has to do.

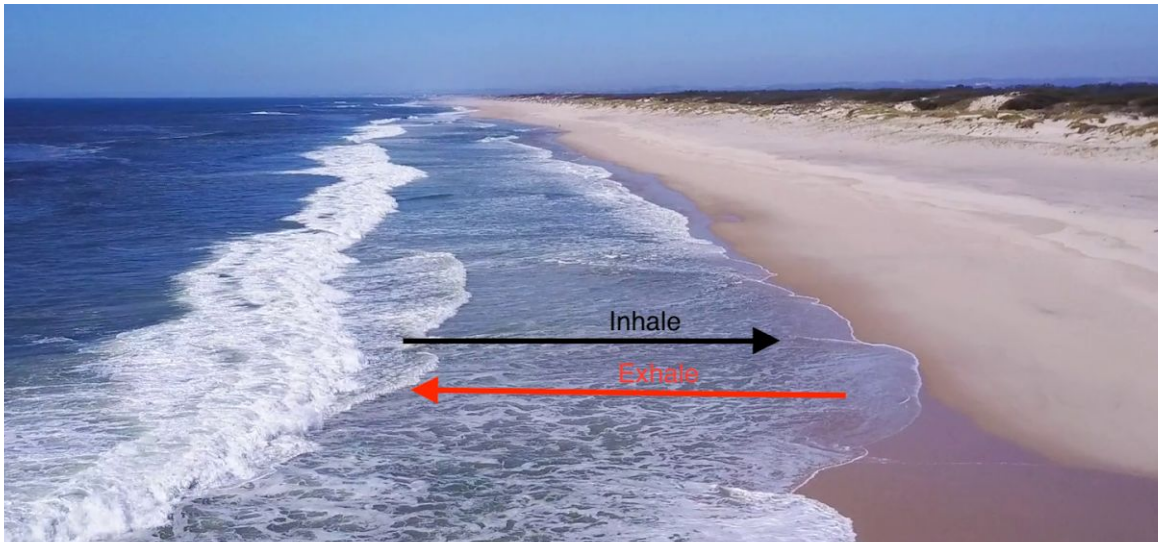


Image 2[2]: Waves coming in and out

4.2.1.2 Pulsating Objects

The second environment will have a space covered in pulsating objects. They will be multicolored in an environment that is nothing like the real world. This alien world will be dark and just covered in these glowing objects that will also pulsate at the rate in which the user has to breathe. These objects will vary in size and color but will all have the same glowing effect so that it can still look like they all belong in the same environment.

4.2.1.3 Wind

The user will be in an area filled with trees, the trees will sway side to side at the rate in which they have to breath. The wind can also move other objects and does not have to be limited to trees.

4.2.2 Visuals

Based on which environment is chosen, it will be further developed to include much more things for the user to look at, be that idle or animating objects. For the beach environments more beachy attributes will be included such as plants and furniture that people would use at the beach such as beach chairs and a beach hut.
For the abstract environment more objects will gradually appear everywhere, also varying in size and color and it will continue to pulsate but not at the exact same time as the other objects surrounding it. The point is to create chaos so that the user will be inclined to focus more on one object.

4.2.3 Biofeedback

The users heart rate and breath rate will be taken throughout the whole test. There are two cases to help with relaxation when it comes to the users biosignals. The environment will react depending on the biofeedback. The already existing environment will go crazy depending on the increased biosignals, so if the beach scenario would be chosen then there would be a storm, with thunder, lighting and large waves. If the one with the pulsating objects was chosen then the objects could get much bigger or more of them will spawn in the area, making it more hectic.

4.2.3 Measurements

The users active and resting heart rate will be taken so that it can be determined at what point they become calm or relaxed while testing out the environments.

[2]https://www.videoblocks.com/video/low-flying-along-over-white-waves-rolling-in-and-out-on-sand-beach-shore-4k-drone-footage-rxidcqp6ej1amey7i

4.3 Technology

The technology that this project will use will be explained here. The Virep project has worked in Unity to create their virtual reality assisted training. This project will also use Unity in order to create the virtual reality assignment, the programming language for the program is C#. Online Unity Assets will also be used to construct and aid in building the project. In order to receive the biosignals from the user a heart rate and breath rate sensor will be used, this has been provided by Roessingh Research and Development. This device is called the Zephyr BioHarness BH3.

Chapter 5: Breathing Environment

5.1 Specifications

The area of the virtual reality world needs to be small enough for the user to walk around in, so that they have the ability to explore the environment. The time in which each of the environments moves to facilitate breathing must be the same amount of seconds, this is 4 seconds.
For the environment testing the waves, the waves need to come in and out clear enough that it is obvious what the rhythm is trying to achieve. This scene will be constructed in a low poly format, which means that although the scene has realistic attributes the way that it is shown will be more game like. For the waves to be created, a script and an object needs to be used in Unity and programmed to the same frequency at which the breathing time should take. Some plants will be added to the island to give the user something else to look at and also to create the feel of an island.

In order to have the trees swaying back and forth, the wind asset from Unity can be used. The trees will have to be placed randomly around an island so that the user can walk around. The built in terrain tool can be used to construct the land and the water prefab from the built in environments assets can be used to simulate water in the area. Water is present so that it can block off the areas that the user is not allowed to walked through, this shows the limits to the scene to the user.

The pulsating objects need to pulse at the same rate but be independent of one another, this is so the user can pick which object they want to focus on. Particle systems will be used to create this and give it an explosion effect. The point of this is to be abstract and not look like anything you would encounter in the real world.

5.2 Realisation

This section will explain how the breathing environments have been made and what they look like. In all the environments the user is free to roam the designated space. The spaces have been made to be small so that a lot of walking or movement is discouraged.

5.2.1 Waves

Initially while constructing the environment with the waves it was not in a lowpoly format. A design choice was made to reconstruct the environment as low poly. Low poly is a polygon mesh normally used for 3D graphics. In Image 3 you can see that having the waves come up the beach and back down have been achieved. To make the user feel immersed into the scene,

sound has also been added. The sound is of waves crashing onto a shore, this sound file will be played on a loop.

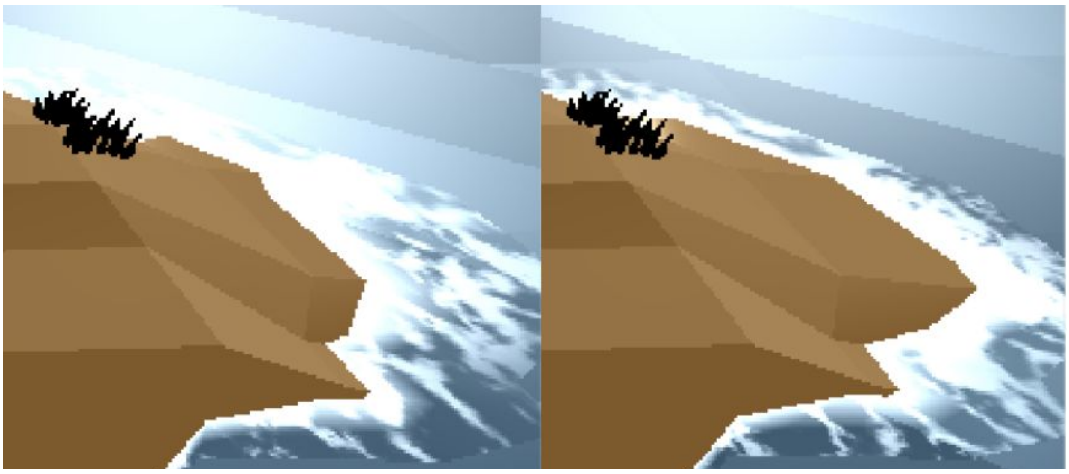


Image 3: Lowpoly waves on a beach, coming in the out again

5.2.2 Wind

This scene was constructed to be more realistic and not in the low poly format. In Image 4 you can see that the environment also consists of an island but this time filled with trees. The wind component from Unity was used to create the wind effect. The trees were from the environment assets that Unity provides for free, the terrain was made with the terrain sculptor built in.

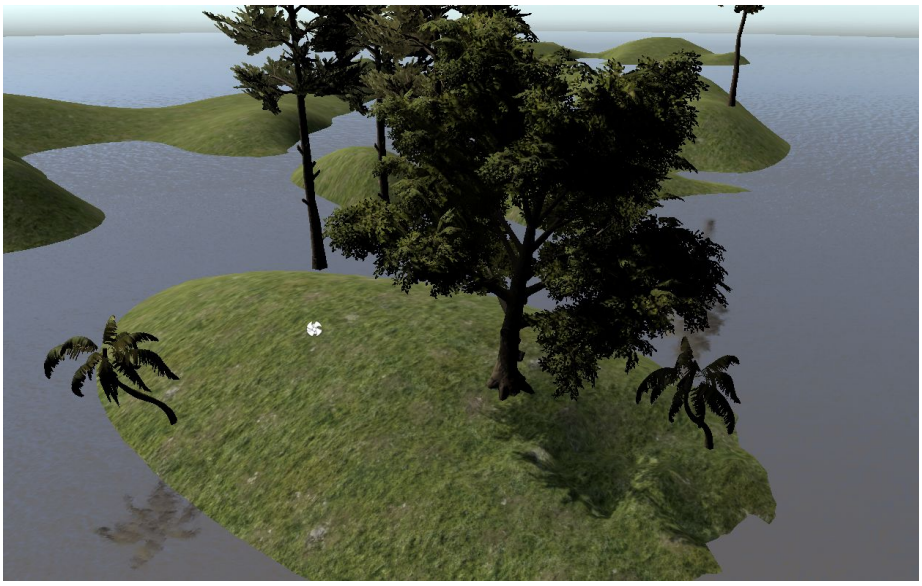


Image 4: Environment where wind helps with breathing

5.2.3 Pulsating Objects

In order to create the pulsating objects in the scene several particle systems were used to achieve this. Instead of having one color pulsating, two colors were used. This was used in order to show when the user should exhale or inhale, it makes it clearer that the colors represent a different task. The user is free to decide how they want to breathe with the objects, but they expand and contract at the desired rate. Image 5 shows 4 pictures on how the objects expand and incorporate the two different colors. The scene also includes an audio file that is also meant to relax the user, it is called Zen Stones[3] and is just music to create an ambient atmosphere.

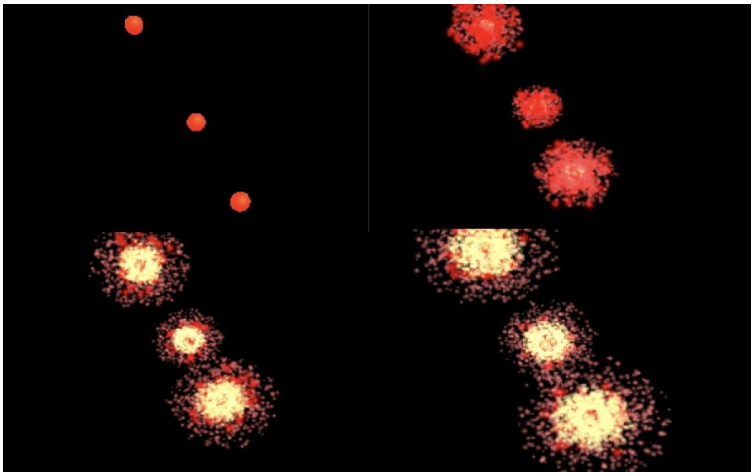


Image 5: Four screenshots of the object expanding

5.3 Usability Testing: Test 1 Breathing Environment

The breathing environment has three different scenes that need to be tested in comparison with each other, in order to find out which design best achieves relaxation. The test plan and procedure can be found in chapter 3.4

5.3.1 Method

This test will be conducted at the University of Twente in the SmartXP. Participants will be students in the surrounding area. A short introduction will be given to the participants. They will then sign a consent form before they start, this can be found Appendix 2. They will then put on the head set and have a few minutes to experience each environment. Once they are done with the first environment they will let the tester know so that they can begin the next environment. After they have been able to experience all three environments they will be given a quick survey to complete about the environments they have just encountered.

[3] Orangefreesounds.com, zen stones, alexander blu

5.3.2 Survey

The questionnaire consists of several questions regarding the design and feel of the environment. The point was to make it clear which environment should be further developed. It consisted of 4 multiple choice questions and two open questions. The following questions were presented to the participants:

Q1: What is your gender?
Q2: What scene did you enjoy the most?
Q3: Which scene did you feel the most relaxed in?
Q4: Could you breathe with the environment?
Q5: Did you understand what the environments were trying to accomplish?
Q6: Do you prefer a realistic environment or an abstract one?
Q7: Do you have any improvements?

The purpose of the questions was to see if the environment did what was intended and feedback to what can be improved, as well as the next steps to take when dealing with the interaction phase of the project.

5.4 Results

In the survey the multiple choice questions at the beginning were used to determine which environment the user preferred and which one they felt to be relaxed in. For this part of the iterative testing 5 participants were involved. For the question of which scene did they enjoy the most it was a tie with the environment with the waves and the one with the wind, while one person chose the one with the pulsating object. The next question asked which scene did they feel the most relaxed in and the one with the waves showed to be the most popular one with 3 people voted for it while the other 2 chose the one with the wind. All participants understood that the environments were helping them breathe, one participant says it was “trying to get me to breathe better”. When asked about having a realistic environment compared to an abstract one 3 of them said they preferred a realistic one because it “feels more natural” and that they “can connect with it more”. The other 2 prefered an abstract one saying that they liked it “so I don't get distracted by details”.

Based on this result the environment to further develop would be the one with the waves that facilitate breathing. The environment is realistic enough, although it is in low poly. The next step will be enhance the environment by adding more elements for the user to look at.

Chapter 6: Visuals Environment

6.1 Specifications

Based on the results of Chapter 5, the low poly island was chosen. To fit with the theme of lowpoly, all the objects used in the environment have to appear to be cohesive with one another, meaning that everything should be in a lowpoly format. The island also has to be the correct size so that the user can walk everywhere in the limited amount of space provided.
The island in the previous phase was empty because it was only being tested for the user to breathe with the waves. Therefore this island needs to be decorated with items that are usually found on an island. The goal here is to find out at which point the island is too cluttered and causes them to not feel relaxed anymore or if the user finds that they can relax in a more cluttered or empty environment. The island needs to have attributes that can be added in steps to test this point. Basic island items include some basic flora and fauna and furniture. Such furniture includes a beach hut, umbrellas and beach chairs. All the items shown on the island will appear to be life size once the user is immersed into the virtual environment. This will make everything appear more realistic to the user when they are exploring the environment.
The user will not be able to have active interaction with the objects in the environment because this can distract them of the ultimate goal of the environment. All the objects will be idle, except for certain things that will be animated, such as the water and the animals.

6.2 Realisation

Based on the results from the testing of the breathing environments the waves environment will be further developed and equipped for further detailing. Therefore an island was created in Unity in order to test at what point do the users become stressed in the environment, and whether or not the clutteredness of the environment affected their mood. The island and the water plane are still the same from the previous phase of 6.1.1. Initially the island was decorated with plants, rocks, animals and beach furniture which can all be found in Appendix 1: Unity Assets.
There are also objects in the distance so that they can look at more things, such as boats far off into the ocean and clouds in the sky. Some of the assets that were used came from the Unity asset store and was called Lowpoly Island and Living birds.

Image 6: Initial Island Size

Image 7: Final Island Size

Image 6 shows the initial island that was created for this phase, but when tested in VR the island was too big so iterations had to be made. The island had to be made much smaller so that the user can walk around and explore most of the environment. Image 7 shows that the island has been made smaller to fit the 2m x 2m area, more assets were also added. Once the island was made smaller the waves on the shore were not so apparent anymore.

Once the island was fully decorated it could be tested. The first thing to be done was to split up the environment into several scenes, this can be shown through Image 8. There were four scenes that were created and could be implemented through the the use of a script that allowed the environment to add the extra components through the press of certain keys on the keyboard. The scenes were split up into: plain island, an addition of rocks, addition of plants and then an addition of human influences such as furniture.

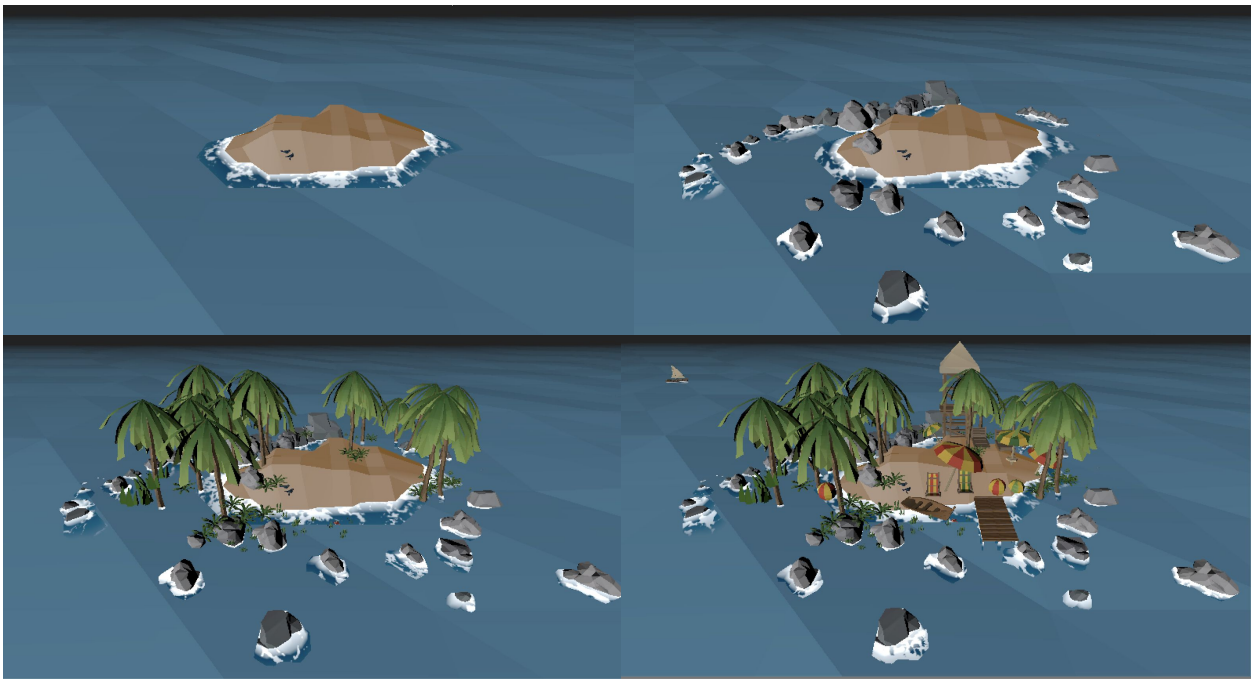


Image 8: Island scenarios

6.3 Usability Testing: Test 2 Visuals

There will be four scenes that the user will be exposed to, each one with more things happening in the environment than before. The goal is to find out at what point do the users not feel relaxed anymore within the environment.

6.3.1 Method

This test will be conducted at the University of Twente in the SmartXP. Participants will be students in the surrounding area. A short introduction will be given to the participants. They will then sign a consent form before they start, this can be found Appendix 2. They will then put on the HTC Vive and earphones and in 30 second intervals a key will be pressed so that more objects will appear in the environment. After they have been able to experience all four scenarios they will be given a quick survey to complete about the environments they have just encountered.

6.3.2 Survey

The questionnaire consists of several questions regarding the design and feel of the environment. The point was to make it clear which environment should be further developed. Questions two until five were asked based on a five point scale. The scale is determined below

for each of the questions that require it. The last three questions are open so the user can write down their opinions there.

Q1: What is your gender?
Q2: I liked the environment.. Empty(1) to Cluttered(5)
Q3: I felt the most relaxed in an.. Empty environment(1) or a Cluttered Environment(5)
Q4: How bored or relaxed did you feel? Bored(1) to Relaxed(5)
Q5: Did you have enough things to look at? Yes(1) to No(5)
Q6: Did you prefer just nature or also the human influence(furniture?)
Q7: Did the sounds help with relaxation?
Q8: What extra things should be implemented into the environment?

The purpose of the questions was to see if the environment did what was intended. It also provided feedback to what can be improved.

6.4 Results

There were eight people who participated in this step of the testing, with 4 being male and the other 4 female. Regarding the second question all the users chose the value 3 or higher meaning that they mostly preferred the cluttered environment, with 3 users selecting the number 4 and 3 selecting the highest option which was 5. This differs slightly to when they were asked if they felt more relaxed in an empty or cluttered environment, where the range was from 2-5. The majority equally chose 3 and 4 with the outliers voting for 2 and 5. This shows that they are more inclined to relaxed in a busier environment, but it also shows that it shouldn't be too busy. They were then asked whether they felt bored or relaxed within the environment and they all gave results that favored the more relaxed side, with half being neutral and the other four on the relaxed side. Boredom or relaxation could be based on what they can look at in the environment which was the next question that asked if they had enough to look at. From the 1-5 scale with 1 being yes and 5 being no, 3 users didn't think they had enough to look at while the other 5 did.

They were also asked if they would like the island free of the human made object, such as the benches, umbrellas and a hut. Overall there were mixed views with one person saying that they liked it because without it they would feel like they were on a deserted island, whereas the furniture “evoked more associations of a holiday resort”. Another person said that they liked it but could use without some of it, such as the benches. The contradictory point was that some thought that the nature was relaxing enough and that the human influence was too extra.

Sound also played a big part with relaxation so when asked about this one said that they were not sure if it made a difference for relaxation but it added contextual value. A few participants complained about the birds, because of their “annoying bird sounds” and that the occasional passing bird would be better. This contradicted with another participant who thought the bird sounds were nice and that the overall sounds were relaxing.

In response to question eight, the main consensus among users was that they would like more animals to be present in the scene and also if there was more movement or animations. A suggestion was that “the sea could be more rough”, which can be done in the next phase. A user also requested a sunset saying that it would be more calming.
These things can be addressed and implemented into the next phase, where the users biosignals will have an effect on the environment.

Chapter 7: Biofeedback

The island from the previous phase will be used for this phase. The point of this phase is to test if mimicking biofeedback or not helps with inducing relaxation. So that when the user has a higher heart rate the environment will mimic this and turn chaotic. This should force the user to want to become calmer so that they can change their surrounding. The alternative is that the environment stays the same in order to aid them.

7.1 Specifications

Based on the results from the previous phase more things will need to be added into the environment. The Zypher bioharness will be needed to retrieve the users biodata and use it as the main input for the environment. The environment is dependent on this input. The following things will be dependent on this data: rain, thunder/lighting, waves, clouds, animals.

The heart rate and the breath rate of the user will be measured throughout the testing period. The application needs to be able to save the users data and not only use it as input into the environment so that their data can be measured. Their biosignals can be plotted against time and see at which points during their experience that their signals fluctuate, you will also be able to see at which point they interact with the environment.

There will need to be a connection made between the Zypher software and the Unity project. The Zypher data can be pulled using a Python script. This script will then save the values coming from the bioharness into a file and this file will be read through another script in Unity. Within the Unity project each object will be assigned to a situation they fit in. Such as the island, rocks, boats, ocean and some of the plants will be the starting island and all the other features will appear or become more drastic as the biosignals are inputted. The birds included will use a flocking algorithm so that they can all fly in unison and not hit each other.
For the most extreme condition of the scene there will be rain, thunder, lighting, large waves, more trees and more animals. Compared to the starting scene these things will gradually increase as the users heart rate increase and vice versa.
There needs to be a clear difference between the start scene and the final scene so that they are not mistaken or unsure what their target scene is.

7.2 Realisation

Based on the results from the visuals phase the users preferred one of the more cluttered options. Therefore the starting island will contain more than just a plain island. Due to this preference the island had to be made with more things happening in it, but it could not be the final island version from the last step because there wouldn't be anywhere to go from there. It will contain the objects shown in Image 9. This image is similar to bottom left part of image 8, it

contains less trees so that more trees can appear for when the heart rate goes up. All of the beach furniture has also been removed and will not be added later because it creates a more secluded island because not all the users liked it when they tested it in the previous phase. The only human element that was kept was having several boats in the ocean moving around and one boat on the island itself.

Image 9: Starting Environment

7.2.1 Stages of the environments.

In order to create the most extreme scene of the island more trees and animals were included. The weather will also drastically change, this includes a thick fog, rain, thunder, lightning and larger waves. All of these things except for the fog has a corresponding sound to it. The rain and waves sound have several sound files attached to them. Different sounds will be used depending on the scenario that the user has created. All the assets that were used to create these stages can be found in Appendix 1: Unity Assets. Image 10 shows the scene with fog and heavy rain applied and larger waves. This will be what the final scene will look like. It will be much darker and chaotic. At the top left of image 10 you can see birds flying in the sky, they will also be present in the initial scene but more of them will appear later on.

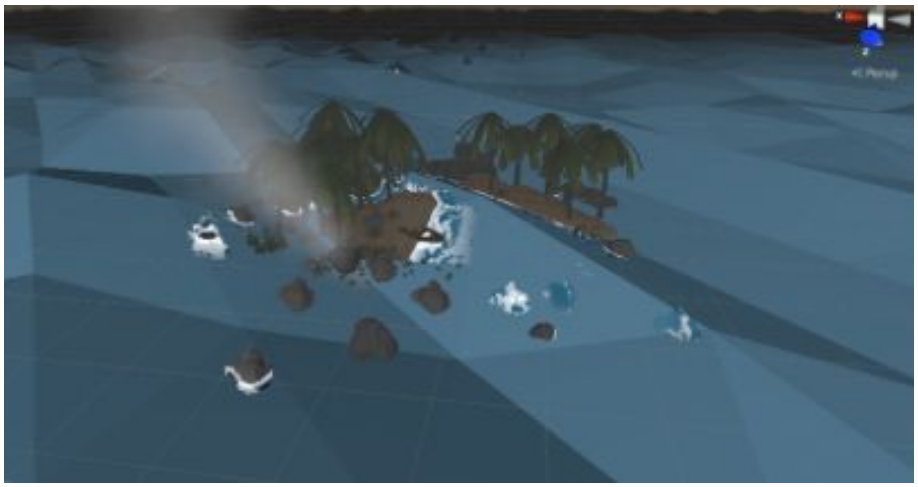


Image 10: Final stage

7.2.3 Animals

All the animals that were used can be found in Appendix 1: Unity Assets. There were 3 different animals involved when creating this final realisation, they were birds, whales and dolphins. Before this there were no animals in the previous stage of testing that had animations. The birds were animated in a way where it looked like they were flapping their wings. In order to make them fly around the island a script was created so that they would rotate around a certain gameobject at a certain velocity. This was similar for the whale where it would also rotate around a certain gameobject so that it would look like it was swimming in the ocean. They were placed at different places in the environment so that they could always be visible to the user. The birds also have sound attached to them, so when they flew close enough to the island then the user will be able to hear them.
The dolphins themselves did not have any animations attached to them but they also circled around a gameobject to give them the illusion that they were jumping out of the water.

7.2.4 Sound

To create a more realistic scenario there was sound attached to the scenes. The sounds got louder as the stages got higher. The sounds that were present were waves, birds chirping, thunder and rain. The sounds involved were from assets that were downloaded from the unity asset store such as Rain Maker. Sound was very important to set the mood, it has the ability to relax or stress out the user depending on the scenario.

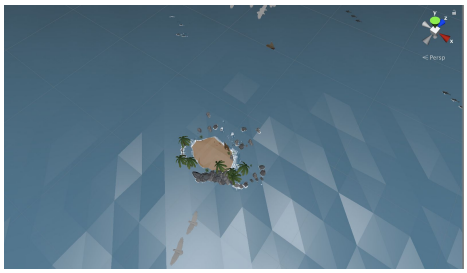
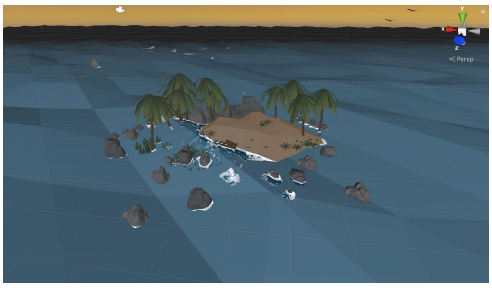
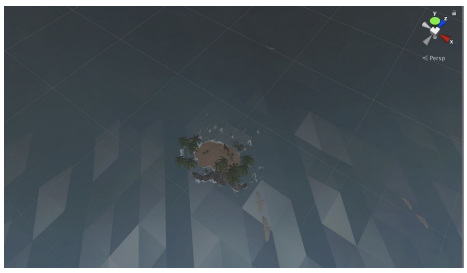
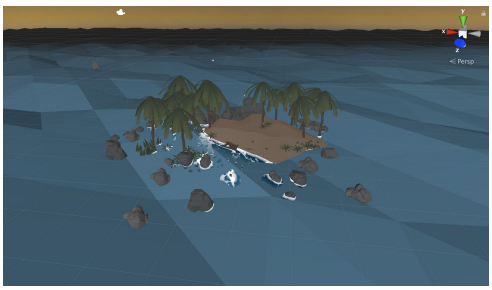
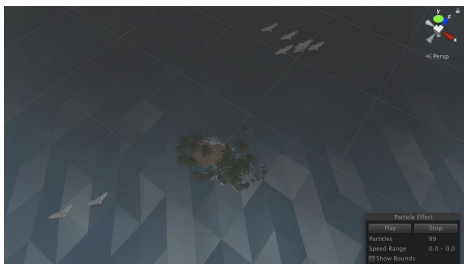
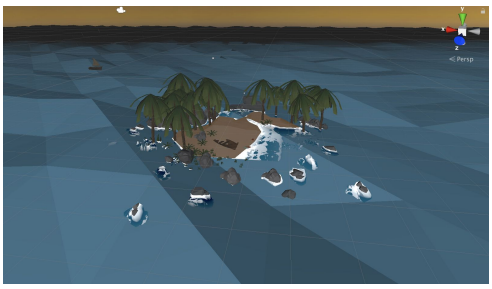
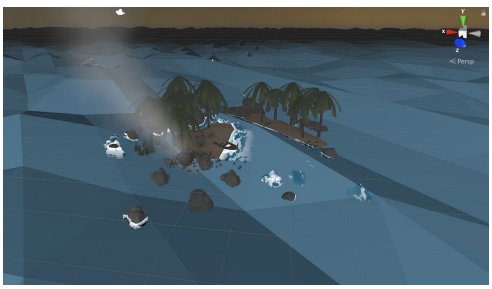
7.2.5 Final

Table 3 clearly shows the 5 different stages and how it would progress while you are in the environment. It shows it from the side view and a birds eye view so that you can see the stages from different angles. Table 4 shows the the breakdown of everything that has been implemented in the five different stages of the environment. You can see what has been added or taken out of the scenes in order to create the effects shown in table 3.

Table 4: Environment Stages and its components

	Stage 1	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**
Trees/Plants	3 x Trees 4 x Plants 20 x Grass	9 x Trees 5 x Plants 40 x Grass	12 x Trees 10 x Plants 40 x Grass	12 x Trees 10 x Plants 40 x Grass	12 x Trees 10 x Plants 40 x Grass
Animals	3 x Dolphins 8 x Birds	6 x Dolphins 10 x Birds 1 x Whale	9 x Dolphins 10 x Birds 3 x Whales	9 x Dolphins 10 x Birds 7 x Whales	9 x Dolphins 10 x Birds 7 x Whales
Rain Intensity (0-1)	None	0.07	0.4	0.71	1
Lightning	None	None	None	Yes	Yes
Clouds/Fog Height	None	None	10	-45	-119
Wave Height (0-1.5)	0.1	0.5	0.8	1	1.5

Table 3: Views of the 5 stages

	Birds Eye View	Side View
Stage 1		
Stage 2		
Stage 3		
Stage 4		
Stage 5		

7.3 Usability Testing: Test 3

7.3.1 Method

Plan A

This is the final testing for this project. This test will be conducted at the University of Twente in the SmartXP and at Roessingh Research and Development. Participants will be students and colleagues in the surrounding area.A short introduction will be given to the participants. They will then sign a consent form before they start, this can be found Appendix 2. This test consists of two parts, the first part the user will experience the the environment where their biosignals do not affect anything and the second test will be the one where their biosignals affect the environment. Each participant will take part in both parts of the tests.

The participant will put on the HTC Vive and earphones and after two minutes of them experiencing the environment they will be asked to take of the HTC Vive to perform some tasks that will elevate their heart rates. Such tasks will include light exercise such as jumping jacks or by gently scaring the user. They then re-enter the environment. Their resting and active heart rate will be taken because this will differ between all the participants.

Test A: When they are back in the environment they again have a few minutes to use the environment to relax.

Test B: Due to their elevated heart rate the environment will be crazier. The user will have to listen to their biosignals and try and relax to make the environment calmer. The test will continue until the user has managed to calm the environment or if the user is taking an excessive amount of time.

After they have been able to experience all four scenarios they will be given a quick survey to complete about the environments they have just encountered.

Plan B

Incase the connection between the sensor and the Unity project do not work the test can still take place through the use of manual input. The sensor data can still be read from a computer screen and based on the values shown on the screen the tester will change the environment accordingly. It should still give a similar result to if the connection was working.

7.3.2 Survey

The questionnaire consists of several questions regarding what the user thought during the testing. The goal of the survey was to also find out whether or not the scene managed to relax them and how and why it did. Question nine asked a question based on a 1-5 scale. The scale is determined below for the questions that require it. The other questions are open so the user can write down their opinions there.

Q1: What is your gender?

Q2: Resting heart rate?
Q3: Active heart rate?
Q4: Did you understand the goal of the testing?
Q5: Which setting helped you relax faster?
Q6: Did you think listening to your biosignals helped you calm down faster?
Q7: Could you tell the difference when the scene changed?
Q8: What aspects of the environment helped you relax?
Q9: Did you manage to relax? No(1) to Yes(5)
Q10: Did you manage to relax? Why?
Q11: Improvements?

The purpose of the questions was to see if the environment did what was intended and whether or not incorporating the user biofeedback proved useful or helpful.

7.4 Results

Plan B of the testing was used. There were 12 people who participated in this user testing, with two being female and ten being male. The genders and the active and resting heart rate of the participants had to be known because this would vary per person and per gender. Their heart rates were taken so that it would be known what values to look for when they appeared to be relax. All the participants answered question five with a yes, which meant they understood the point of the testing and when asked which environment helped them calm down faster there was a 50:50 split between the two testing scenarios. They were then asked if listening to their biosignals helped them calm down faster and only 7/12 thought that it did. The others said that “It was interesting to see yourself become relaxed but I don't think it helped” and “In the beginning it doesn't help because it is a more stressful environment. But after a while you notice that you can calm down the environment by calming down yourself”. These 5 participants said it did not help or were unsure of it. The answer to question 8 mostly consisted of that the sunset helped the most and the users were also very happy with the animals that were present and that watching the animals were some of their best moments. They also really enjoyed the sounds of the waves with 7/12 participants mentioning it.

75% of the participants thought that they managed to relax within the environments, but they came up with a lot of reasoning for this. One participant said “Yes, but I don't know if the scene helped as much as just standing still” which contradicted with “yes, because I often relax when I don't have to do something” and “Yes, I feel like I calmed down in both environments, I'm not sure how much the changing in environment added in the second scene but I didn't feel an added effect.” All the users agreed that they did feel relaxed but their explanations explained it in further detail, saying that it may not be because of the environment, this is why only 75% thought the environments helped them relax.
The participants suggested several improvements to the project once they were done with the testing. The main one was to have the transition between the stages to be smoother. One participants said that the boat on the island made it seem like you were shipwrecked which may

scare people, but there was only one person who mentioned the boat. Another suggestion was to fix some of the motions created by the HTC vive, where if you looked up the headset would make you look in a different direction. Finally a few participants said that the birds should not be animated in the same animation cycle, just so that it would appear to be more realistis.

Observations were also made throughout the whole testing period. Based on observation it could be seen that the users heart rate would mostly decrease at a faster rate in the second testing scenario rather than just the calm scenario. There were a few participants whose heart rates would go up after the stages changed because was too abrupt. Their heart rate would raise slightly or reduce very slowly while they were exploring the scene, this observation was made in almost 50% of the participants.

Chapter 8: Discussion

In this chapter all the results that have been found will be discussed and explained. It discusses whether the goals of the project have been reached and what could be done to improve them.
The goal of the project was to create a virtual reality relaxation environment that was an extension on the Virep project, where the user who is doing stressful rehabilitation therapy can find a quick and easy way to relax. The Virep project worked with people who suffered from chronic pain. This project made a relaxation environment in the end, but the main goal was not to tailor it to people with chronic pain but to first figure out if anyone could even relax within this environment.

Using the iterative design testing method was a good way to grasp early on what the user wanted in a relaxation environment. The two testing phases ultimately led to the final result of the project, which was a low poly island where the waves could be used to help with breathing. The issue with integrating biofeedback into the environment was that the user was more focused on what was happening around them rather than finding something to focus on that would help them breathe and relax.

The final result was that 75% of the participants found that they managed to relax within the environment. That is a good outcome for this research, but of course there are also factors that can lead them to this result. After elevating their heart rate through exercise the time it took for the users heart rate to get back down again varied, this is due to their different fitness levels. Their heart rate will naturally come down anyway once the exercise stops and taking the time in which they can reduce their heart rate would also not be an accurate measurement of the impact of the environment. As everyone is different, they all had different times in which they returned back to their resting heart rate. Also with exercise their heart rate would be much higher than someone who would be stressed, so for the environment to be able to mimic the user it would have to be tailored to the specific person per test. Otherwise their heart rates would not be in the range of the 5 stages.
To have a more accurate testing for the relaxation environment would be to introduce the user to stress instead of exercise because it would be more closely related to the people who would use it during rehabilitation training.

8.1 Future Work

The main feature that needs to be added to this project is actually integrating the bioharness into the environment as a direct input, because what was done during the testing was a manual input based change instead of fully relying on the technology. This would mean that the application would be fully functional without having anybody to supervise the user.
Regarding the application, the users biosignals could also be projected into the virtual reality world, but this could pose as a distraction to the environment because then they would only focus on trying to lower value and not use the environment to help them. Another suggestion to

this would be to add more sounds, such as their heart beating, so that when they have a high heart rate then they would hear it louder and faster and vice versa for when they are calm. This seems to be a less intrusive way of showing them how their bodies are reacting.
In the final testing one of the participants explored that this project could also be used for children who have ADHD as it can help them to calm down and not become so hyperactive and because it is virtual reality they would be more inclined to using it because of its game like assets.

In order to be a true extension of the Virep project this project will also need to be tested on people who actually suffer with chronic back pain, and the raised heart rate should not be because of exercise but actually because of the stressful rehabilitation. Testing with these people would gather more results to see if it can appropriate in order to aid and help them relax.

Chapter 9: Conclusion

This chapter will conclude the findings from the research and answer the main research question.
The main research question was:

> “To what extent was the relaxation environment successful?”

In regards to creating a virtual reality relaxation environment that had the ability to listen to your body signals it was found in the final testing stage that 75% of the participants managed to relax. This would show that it was 75% successful in achieving the goal of the research which was to create a relaxation environment. It was also found that 60% participants thought that listening to their biosignals helped them to relax. Meaning that more than half found it as a helpful tool for relaxation. This research manage to achieve its goal, but there are still many attributes that are lacking and there are many places for improvement. The next goal should be a 100% success rate for achieving relaxation, because patients with chronic pain may have a harder time relaxing than the regular person.

Appendix

1. Unity Assets

The following assets can be found in the Unity Asset Store and have all been used in order to create this graduation project.

1. **Animals:** http://quaternius.com/assets.html?i=1

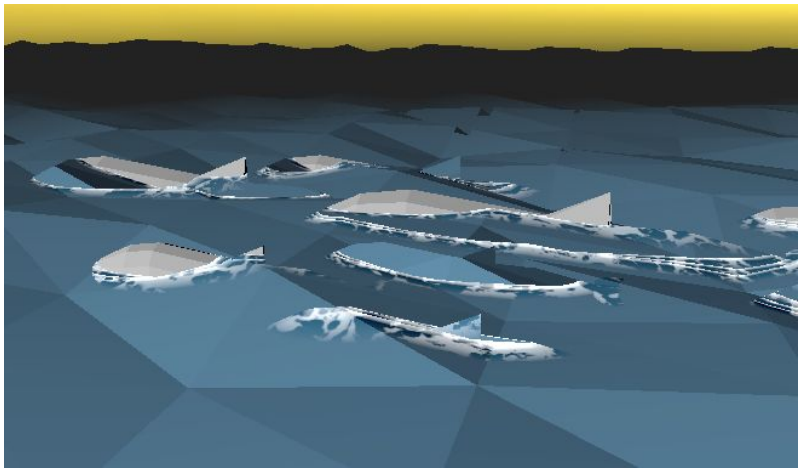


Image 11: Whales

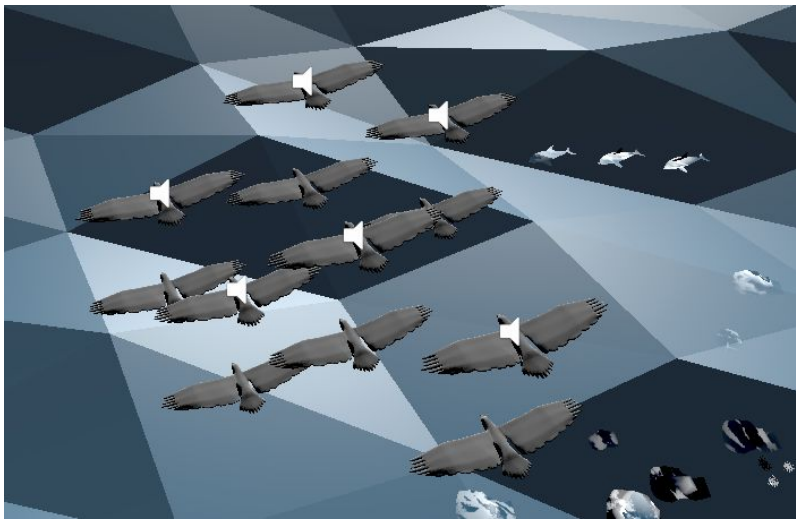


Image 12: Birds

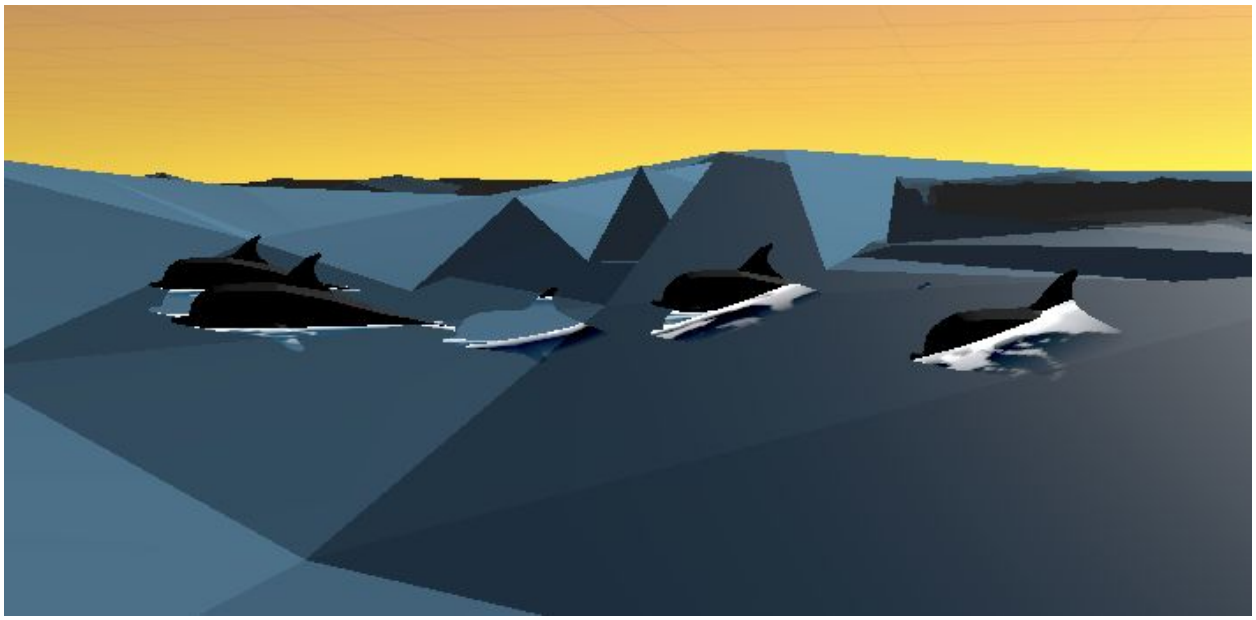


Image 13: Dolphins

2. **Livings Birds**: https://assetstore.unity.com/packages/3d/characters/animals/living-birds-15649
3. **Lightning Bolt:** https://assetstore.unity.com/packages/tools/particles-effects/lightning-bolt-effect-for-unity-59471
4. **Low Poly Beach:** https://assetstore.unity.com/packages/3d/environments/landscapes/low-poly-beach-87244
5. **Low Poly Nature Assets:** https://assetstore.unity.com/packages/3d/environments/low-poly-nature-assets-sample-67201
6. **RainMaker:** https://assetstore.unity.com/packages/vfx/particles/environment/rain-maker-2d-and-3d-rain-particle-system-for-unity-34938
7. **Steam VR:** https://assetstore.unity.com/packages/templates/systems/steamvr-plugin-32647

2. Consent Form

Virtual Reality Testing Consent Form

I declare herewith that I have been informed both verbally and in writing and in a manner that is clear to me concerning the nature, method and purpose of this research. My questions have been answered to my satisfaction. The written information which accompanies this declaration has been handed to me. You will complete one of the following tests.

This test will require you to explore a virtual reality environment that is meant to make you relax.
Test 1
You will be able to explore 3 different scenarios that will help you control your breathing.

Test 2
You will be in an environment that will add objects to make it more crowded at a certain interval.

Test 3
You will first be subjected to light exercise as a way to elevate your heart rate, after this you can enter the environment. There are two parts to the test so you will have to elevate your heart rate two times. You will also be attached to a bioharness so your signals can be monitored. This data will be collected so that it can be analysed.

I am willing to participate in the testing. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason.

_____
Signature

_____
Date

Contact Information
Name: Yasmin Salce
Email: y.p.salce@student.utwente.nl

3. Survey Questions

Test 1: Breathing

Q1: What is your gender?
Q2: What scene did you enjoy the most?
Q3: Which scene did you feel the most relaxed in?
Q4: Could you breathe with the environment?
Q5: Did you understand what the environments were trying to accomplish?
Q6: Do you prefer a realistic environment or an abstract one?
Q7: Do you have any improvements?

Test 2: Visuals

Q1: What is your gender?
Q2: I liked the environment.. Empty(1) to Cluttered(5)
Q3: I felt the most relaxed in an.. Empty environment(1) or a Cluttered Environment(5)
Q4: How bored or relaxed did you feel? Bored(1) to Relaxed(5)
Q5: Did you have enough things to look at? Yes(1) to No(5)
Q6: Did you prefer just nature or also the human influence(furniture?)
Q7: Did the sounds help with relaxation?
Q8: What extra things should be implemented into the environment?

Test 3: Biofeedback

Q1: What is your gender?
Q2: Resting heart rate?
Q3: Active heart rate?
Q4: Did you understand the goal of the testing?
Q5: Which setting helped you relax faster?
Q6: Did you think listening to your biosignals helped you calm down faster?
Q7: Could you tell the difference when the scene changed?
Q8: What aspects of the environment helped you relax?
Q9: Did you manage to relax? No(1) to Yes(5)
Q10: Did you manage to relax? Why?
Q11: Improvements?

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