# Underwater VR System for Overcoming Fear of Water

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## ABSTRACT

Virtual Reality technologies have been growing dramatically in many areas in the world, one of the most important contribution of it is the Virtual Reality therapy, people have utilized the VR technologies to overcome different medical challenges. This project is mainly target on how can we use the VR technologies to overcome the mild Aquaphobia, people who suffered from mild Aquaphobia is discomfort in the water which makes them over anxious in the water and always struggle to swim, this troubles a lot of people in their daily life. Therefore, we designed a underwater VR headset and conducted a experiment to help people who is fear of water or drowning to overcome their mental block, firstly we designed a VR headset which is able to display different VR scenarios underwater for users to make them feel more comfortable and distract their attention from the uncomfortable feeling, secondly, we detect their heart rate as the indicator of their feeling and collect the experimental data to analyze the result. We found that VR technologies is also able to help the Aquaphobia patients, the user's average heart rate is able to decrease up to 3 times per minutes after they wear the underwater VR headset for a while.

## KEYWORDS

Aquaphobia, Virtual Reality

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## 1 INTRODUCTION

Aquaphobia or waterfright is a persistent and abnormal fear of water [1].Aquaphobia is a specific phobia that involves a level of fear that is beyond the patient's control or that may interfere with daily life [2].People suffer aquaphobia in many ways and may experience it even though they realize the water in an ocean, a river, or even a bathtub poses no imminent threat. They may avoid such activities as boating and swimming, or they may avoid swimming in the deep ocean despite having mastered basic swimming skills. And aquaphobia contains different levels of manifestations through a combination of experiential and genetic factors [3]. These manifestations such as choking sensation, discrete panic attacks and so on can have a profound effect on a person's health, work, confidence and overall wellbeing.

Virtual Reality (VR), is one of the current dominant trends in technologies which has bloomed in many different areas such as gaming, clinical and medical treatments, and even in some special types of training. While much focus on the implementation of VR on the gaming area, we still cannot ignore its wide application in medical treatments, especially the contribution of Virtual reality therapy (VRT).

Virtual reality therapy (VRT), also known as virtual reality immersion therapy (VRIT), simulation for therapy (SFT), virtual reality exposure therapy (VRET) [4], and computerized CBT (CCBT), is a method of psychotherapy that uses virtual reality technology to treat patients with anxiety disorders and phobias where it has proven very effective [5]. It is now one of the effective treatment for curing phobias. The traditional method of VRT is making the patient exposed to the VR system and meanwhile a therapist takes the charge of the whole system to assist the therapy [6].

Based on the various level of aquaphobias, this paper's design mainly focuses on treating people with a light sign of aquaphobia, which is anxiety or fear, and helps them enjoy the experience of swimming. The goal of this paper is to explore a new practical option to implementing virtual reality technologies with water-discomfortable people immersing themselves in the real water environments. The novel point is those people do not have to accept their phobia scenarios from the VR device but they stay in the scenarios with VR equipment to reduce and distract their fear by playing pleasant VR videos.

We proposed a hypothesis that regards our underwater virtual reality design can work effectively to release people's fear of swimming and we conducted an user study to research. According to threoritical fundamental from "Physiological measures of presence in stressful virtual environments" by M. Meehan, B. Insko, M. Whitton, F. P. Brooks, the level of anxiety can be measured and analyzed by Heart Rate and Heart Rate Variability. We carried out a series of experiments with two users of light aquaphobia. Through testing and recording their change of heart rate when swimming with virtual reality headset, we compared the gathered data with their normal heart rate and made effective analysis. Finally, from the processed data, we observed that when the users are wearing the VR headset underwater, their heart rate shows more similar with the normal condition compared to when without the immersion of VR environment. So the conclusion is that virtual reality technology can contribute to the alleviation of people's light aquaphobia.


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## 2 RELATED WORK

There have been a lot of researches and related words researching the therapeutical ability of the virtual reality. There are now many substantial virtual reality therapy (VRT) developments and applications, as we have mentioned in the introduction chapter, virtual reality exposure therapy and virtual reality immersion therapy are all are widely used in many situations effectively. The existing application where virtual reality plays an important role in phobia treatments includes specific phobias such as fear of flying, fear of driving, fear of heights, fear of public speaking, fear of thunderstorms, claustrophobia, agoraphobia, arachnophobia, social phobia, panic disorder, and post-traumatic stress disorder (PTSD) due to motor vehicle accidents. Now VRMC (Virtual Reality Medical Center) currently uses virtual reality exposure therapy (3-dimensional computer simulation) in combination with physiological monitoring and feedback to treat panic and anxiety disorders.

One of the most measured and popular therapy of virtual reality therapy to overcome different types of phobia goes to the virtual reality exposure therapy. From the previous research, the most famous and representative case for VRET is Virtual Iraq Exposure Therapy application for PTSD which successfully cured the PTSD of patients who have experience of actual or threatened death or serious injury and patients who was involved in military combat and violent personal combat [7]. Virtual Iraq/Afghanistan consists of a series of customizable virtual scenarios designed to represent relevant Middle Eastern VR contexts for exposure therapy, including a city and desert road convoy environment. During the curation, the veterans are required to re-experience various war scenarios from the virtual reality equipment with sounds and olfactory sense. Besides, the clinician is in full audio contact with the patient to customize the therapy experience to the individual needs of the patient. Results from an open clinical trial using Virtual Iraq with 20 treatment completers indicated that 16 no longer met PTSD diagnostic criteria at post treatment, with only one not maintaining treatment gains at 3-month follow-up.

Except for those severe pathologic situation in the previous case, many other phobia cases which are more popular and less severe in people's daily life have also been proven that they can be conquered by virtual reality therapies effectively. First of all, people use virtual reality to help children to overcome fear of water. A Swedish project aimed at treating light aquaphobia symptom from water-fearing children by VRT [8]. The underwater video demonstrated the power of VR, with each aquaphobic child sitting down to try on the headset and view the footage involving the three Olympic stars. The change seemed to happen immediately, as the children got to 'experience' a swimming pool-in virtual form -for the very first time. After initial hesitations, it's obvious that each child warms to the idea, and by the end of they can't wait to try the real thing. Furthermore, João P.Costa, James Robb and Lennart E. Nacke used VR technology to cure the Physiological acrophobia problem[9] and Larry F.Hodges and his team help people to overcome the fear of flight and the fear of height [10].

Another research explores how can we evaluate the uncomfortable feeling level or anxiety level, The study of "Feasibility of Training Athletes for High-Pressure Situations Using Virtual Reality" [11] provides a very straightforward method to evaluate the level of anxiety during the high-pressure sports, in which they use the Heart Rate (HR) and Heart Rate Variability (HRV) to evaluate the anxiety of the athlete [12], both HR and HRV can be measure directly or indirectly by the smart band in our system, another indicator in the paper is Galvanic Skin Response (GSR) which can be measured by a simple fingertip sensor.

**Figure 1: Basic structure of the underwater VR headset.**

## 3 INTERFACE DESIGN

### 3.1 Equipment and Structure

The equipment is consisted of two different parts. The first part is underwater VR, the second part is heart rate monitor.

Underwater VR contain snorkelling mask, VR lens and smartphone. The snorkelling mask is free breathing design; it allows the people who don't know how to take a breath underwater or the user is struggling in the water to enjoy the experience of skin dive. VR lens is come from google cardboard. And smart phones with supported VR applications (e.g. Within) are used as screen to show the VR video. Put the phone is sealed in a waterproof bag in order to protect the phone. Fig.1 and Fig.2 illustrates the frontal figure of our underwater VR headset with and without the smartphone.

As we can see from the above figure, the long black pipe locates on the top of the headset if the snorkel to ensure users who have different levels of aquaphobia to breath fluently, the headset has a transparent mask with a transparent waterproof sealable bag to locate the smartphone, furthermore, there is a piece of paperboard inside of the headset with two stereoscope lens which are destructured from the Google Cardboard to provide stereo vision for users as we can see in the Fig. 3.

There are several motivations that why we design our underwater VR headset like this, first of all, if we locate all components (waterproof bag, stereoscope lens and smartphone) inside of the headset, the space in the headset will be extremely limited and it will also weaken the leakproofness of the headset. Secondly, if all components are located outside of the mask, we have to consider the refraction effect of the water, this will distort the VR vision

**Figure 2: VR headset combines with sealed waterproof smartphone.**

**Figure 3: Inside structure of the headset.**

and also considerably complicated to solve. Therefore, our design finally come up to locate the lens inside of the mask and adhere the waterproof bag with the smartphone closely outside the mask, in this case, not only we can save the space inside the headset, but also we can minimize the effect of the water, and all components are transparent which is good for the user to see the VR display of the smartphone.

Fig. 3 displays the inside structure of the headset clearly, we can see that in our design we have enough space to locate the lens and we also save a lot of spare space for the use with different face shapes to wear the equipment comfortably.

In this project, heart rate was used as a parameter to show the result of this underwater VR. At first when a water-discomfort user


**Figure 4: Polar sensor(right) and training computer(left).**


**Figure 5: User illustration upon the water.**

gets into the water, he or she will become very anxious and the corresponding physiological response is that the heart rate increase quickly. Heart rate monitor produced by Polar was used in this project. This monitor has two parts, one watch and one heart rate sensor. The sensor should be clipped around the chest and adjust the strap to fit snugly. After about 20 seconds, the heart rate will show on the watch. We can record all of the rate data and then compare the data in different situation. The equipment is shown in Fig. 4.

## 3.2 How to Use

When the user is using this equipment to conquer the aquaphobia, the user wears the snorkelling mask. The lens inside and the smartphone outside the mask provide a virtual reality environment through the transparent mask. The mask can help user breath under water. At the same time, the user wears the heart rate sensor to measure the heart rate. The Fig. 5 and Fig. 6 illustrates the user figure below.

**Figure 6: User underwater.**

# 4 USER STUDY

## 4.1 Research Question

The user study is aimed to verify the following hypothesis:
RQ1: Will users with light aquaphobia release anxiety and fear when applying underwater virtual reality technology to their swimming experience?
RQ2: If users perform better with VR headset in the water, how do they think about the effects of underwater VR?

## 4.2 Theoretical Background

This project is aimed to help swimmers to overcome their drowning or swimming phobia issue by using underwater VR system. The VR technologies have been widely used in psychotherapy to overcome or release some specific sorts of fear, for instance, João P. Costa, James Robb and Lennart E. Nacke used VR technology to cure the Physiological acrophobia problem [8] and Larry F.Hodges and his team help people to overcome the fear of flight [9] and the fear of height [10]. However, almost all the existing researches in VR therapy are using the VR exposure therapy [13] in which the user do not need to be personally in the scene but just use the VR to simulate the required scenario. This method is not perfectly suitable for our project, the reason lies in the fact that unpleasant feeling of drowning is the most basic reason of low-level aquaphobia, we cannot simulate the realistic feeling of drowning virtually, therefore, the user should immerse himself in the water to do the test instead of do purely virtual test by VR in some save place.

From our literature review, we found that heart rate can be considered as the indicator to describe the level of anxiety as well as phobia and attention distraction can alleviate people's fear. Firstly, Risty A Johnstone and Andrew C Page's research [14] proves that distraction can be used to reduce the level of anxiety effectively, therefore, we are going to design the first VR model which transforms the tedious swimming pool to a more colorful underwater ecosystem which contains different marine animals to distract the swimmer's attention from his bad feeling of water. Secondly, according to Ana Paula Cláudio's study [15], different virtual environment(VE) is also able to release the user's anxiety as well. Therefore, the second suggested scenario is even more distractive. If the underwater environment can make swimmer who has slight aquaphobia over nervous feeling, we will totally change the environment for swimmers. In other words, the VR device will display a non-water scenario which the water fear swimmer is more familiar with in his daily life during his swimming experience. Through this way, the swimmer would be implied that he does not stay in the water by the created VE to some extent, which increases possibility to help the user get used to the drowning condition and overcome aquaphobia. The last theoretical basis is from the study of "Feasibility of Training Athletes for High-Pressure Situations Using Virtual Reality" [11]providing a very straightforward method to evaluate the level of anxiety during the high-pressure sports, in which they use the Heart Rate (HR) and Heart Rate Variability (HRV) to evaluate the anxiety of the athlete [12]. So we analyzed the collected heart rate data to determine how to describe and evaluate the uncomfortable condition or anxiety level of the swimmer who has slight aquaphobia.

## 4.3 User Study Stages

We tested user's heart rate collected from 3 different VR scenarios designed for this experiment and analyzed measured heart rate as the results, further figured out which one is the best suggested treatment for drowning phobia.
Stage 1: Record users' original heart rate by equipping them with normal swimming goggle without any VR therapy.
Stage 2: Record users' heart rate by equipping them with a VR headset which displays an underwater world for distraction purpose to evaluates the treatment effect of distraction.
Stage 3: Record users' heart rate by equipping them with a VR headset which displays an underwater world for distraction purpose to evaluates the treatment effect of distraction.

We have three volunteers for user study, two of whom are males and one is female. The volunteers are definitely willing to swim but slight aquaphobia bothers them for a long time so that they cannot totally enjoy the fun brought by swimming. In the experiment, all of them followed the above three steps and we followed their heart rates from the polar transmitted belt tied around their chests.

## 4.4 Data Collection and Analysis

According to the three volunteers, we gathered three different datasets. The 'Before', 'After 1' and 'After 2' means user wearing normal mask and snorkel, wearing VR headset displaying colorful marine environment and wearing VR displaying a scenario they choose themselves respectively. In these tables, every record lasts for one minutes and the heart rate stands for user's average heart rates in one minutes.

From the above tables, we analyzed the data and compared trends of changing. Finally, we acquired reasonable trends as we expected,

The horizontal axis represents the three different VR scenarios and the vertical axis represents users' heart rate per minute. The error bars illustrate three users' heart rate fluctuation tendency in

**Table 1: Male one's record**

| Male one | Record 1 | Record 2 | Record 3 | Record 4 | Record 5 | Record 6 | Record 7 | Record 8 |
|---|---|---|---|---|---|---|---|---|
| Before | 79 | 78 | 79 | 77 | 79 | 79 | 78 | 79 |
| After 1 | 83 | 80 | 79 | 78 | 76 | 76 | 77 | 76 |
| After 2 | 82 | 81 | 78 | 77 | 77 | 76 | 75 | 75 |

**Table 2: Male two's record**

| Male two | Record 1 | Record 2 | Record 3 | Record 4 | Record 5 | Record 6 | Record 7 | Record 8 |
|---|---|---|---|---|---|---|---|---|
| Before | 78 | 78 | 80 | 77 | 75 | 79 | 79 | 78 |
| After 1 | 84 | 80 | 78 | 77 | 78 | 75 | 75 | 76 |
| After 2 | 79 | 79 | 78 | 77 | 77 | 76 | 76 | 77 |

**Table 3: Female one's record**

| Female one | Record 1 | Record 2 | Record 3 | Record 4 | Record 5 | Record 6 | Record 7 | Record 8 |
|---|---|---|---|---|---|---|---|---|
| Before | 89 | 87 | 87 | 88 | 87 | 86 | 87 | 88 |
| After 1 | 87 | 88 | 85 | 86 | 84 | 85 | 85 | 84 |
| After 2 | 84 | 87 | 85 | 85 | 85 | 84 | 86 | 84 |

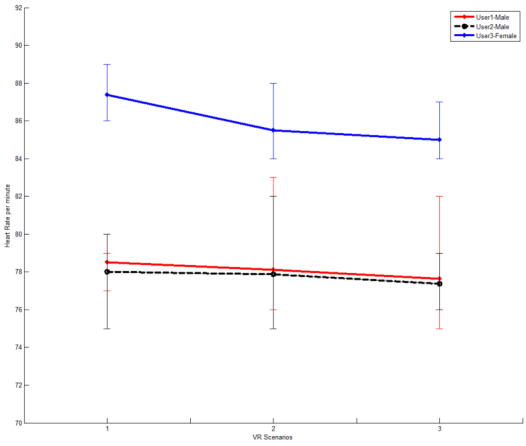


**Figure 7: Trend during 8 Minutes.**

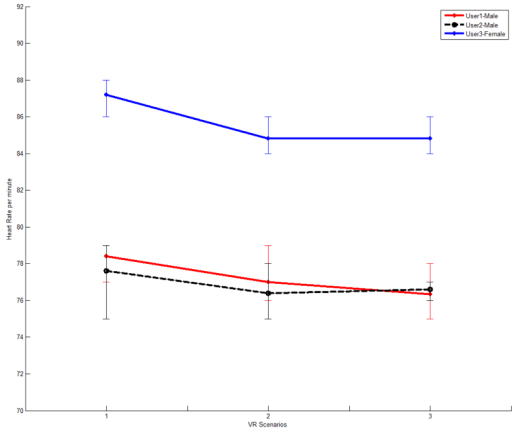


**Figure 8: Trend during the Last 5 Minutes.**

three scenarios respectively, the two poles of each error bar reflects the variation range of the corresponding dataset.

The top blue line reasonably presents female user's heart rate in both figures due to the fact that female's heart rhythm runs from 1.7 to 2.3 hours ahead of her male partners' which represented by the lower red line and black line. It is easily observed that in the 8-minute figure, the heart rate decreasing tendency is not obviously observed, and its error bar's range is larger than its 5 minutes counterparts, especially lines for two male users. This is mostly due to the fact that users normally spent 1 to 2 minutes to gradually get used to the VR headset and then totally immersed themselves in the VR world, therefore, most of the first one or two records of wearing VR headset in the table are relatively big, and then, these values went down rapidly in the second or third minute indicates that the users are get used to wearing the VR headset.

For better observation, we plotted the second figure which records the last 5-minute changing trend when users are totally get use to the headset where we can view relatively distinct changes in heart rate and ignore the influence created by users' adaptation time period. Apparently, users' mean heart rate declined to normal standard when placing them in marine VR scenario or in their preferable VR scenarios. Furthermore, we can conclude from the data that the average best performance is derived from user's preferable scenario.

## 5 RESULTS

From the above figures and the data analysis, it is evident that the blue line stands for the data of the female user is always higher than its male counterparts (Red and Black Line), this phenomenon corresponds the fact that females' average heart rate per minute is normally higher than males' which proves the validation of this experiment. In Fig. 7, the average heart rate of the female user decreases 2% and 2.6% from the condition without the VR headset to using VR scenario 1 and scenario 2 respectively. The two lines for the male users are vary less obvious then the female user, they just decline at most 0.8% and 0.7% respectively from the original situation to using VR scenarios. And the error bar of all conditions in the figure 5 fluctuates drastically, this is because users often feel uncomfortable when they just started to wear the VR mask in the first 1 to 2 minutes, the data becomes more stable after the third minute time slot.

Figure 6 focus on the experimental data in the last 5 minutes, in this case, most of users started to get familiar with the feeling of wearing the VR headset, the data at this period is more stable and reasonable than the 8 minutes' period which includes the adaption period. We can see that the female user's average heart rate decreases at most nearly 3% from original situation to wearing the VR mask with scenario 2, the first male user who represented by the red line, the second VR scenario works better on him. his average heart rate decreases over 3% from wear nothing to wearing the VR mask with second VR scenario. However, the second male user receive a better performance when he was using the first VR scenario, his average heart rate decreases 1.5% from none to the first VR scenario.

As expected, according to the theoretical background that heart rate can be regarded as an indicator to describe levels of anxiety and fear, the decreasing heart rate trends from data analysis support our hypothesis that the underwater VR scenario contributes to help people overcome or release slight aquaphobia. We also found that when users kept focusing on their interested VR video in the third scenario experiment, their mean heart rates from the above tables show subtle decrease and are closer to their normal status compared with heart rates from marine scenario. Besides, after the experiments, users all indicated that the underwater VR system can not only distract their attention from focus on the water, but provides them with a new mode to enjoy the maximum when they are swimming.

## 6 CONCLUSION

In this paper, we explored the probability of using the self-designed underwater virtual reality headset to help patients who has mild Aquaphobia which makes them discomfort in the water to overcome the fear of drowning in the water. Based on the past successful experiments f the VR therapies, we assessed our hypothesis by designing a water underwater VR headset which combines with the stereoscope lens and the water proof transparent bag to locate the smartphone which lets us to detect and compare users' heart rate with and without wearing VR headset. We have designed 3 different scenarios which are without any VR, with VR scenario 1 which is the common colorful underwater world and with VR scenario 2 which is a preferred model chosen by the user, we have concluded from our experimental results that female users are always has higher average heart rate than their male counterparts in all cases and VR scenarios can truly help the water-fear patients to make them more clam in the water with at most over 3% heart rate decrease.

## 7 FUTURE WORK

The possible areas of improvements can be performance improvements of the VR equipment by adding the waterproof headset to provide ambient sounds of different VR scenarios to make the system more realistically, besides, the experimental data may be influenced by the DIY hardware limitation which sacrifices the comfort of the equipment, therefore, If we are able to get more advanced hardware in the experiment the data will be more accurate and meaningful. Secondly, the biofeedback technologies could be added to the system to provide better interaction performance for users by adjusting the virtual environment adaptively. Furthermore, strong data mining models and algorithms can be further used to analyze the experimental data to excavate more potential information.

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