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Conquer Catharsis – A VR Environment for Anxiety Treatment of Children and Adolescents

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Abstract. In this paper we present a novel VR-based tool for the treatment of anxiety disorders for children and adolescents. The tool consists of a photo-realistic VR game, together with a biofeedback device, and a second screen for enabling interventions for the practitioner. We describe the tool, how we measure and use biofeedback, and evaluate the sense of felt presence of a group of experimental participants.

Keywords: Virtual Reality · Children · Anxiety Treatment · Relaxing

1 Introduction

The aim of Conquer Catharsis is to create a biofeedback-therapy simulation game that utilizes virtual reality and gamification to create an immersing and fun environment for children and adolescents with anxiety disorders to practice relaxation. The main goal is to create a therapy game that would make relaxation training more enjoyable, but also act as a research tool.

As the main biofeedback metric for relaxation, the patients' current average heart rate is chosen (HR), the main goal of the system being to teach patients to relax and thus reduce their HR at will. As feedback, progress is symbolized by gradually making a forest bloom again as the heart rate is reduced. The technical goals include:

- Create an environment that can be explored in VR for relaxation training.
- Integrate communication between an HR sensor, an external control app for the psychologists, and the VR game.
- Use HR-Sensor data to drive gameplay elements.
- Evaluate presence and perceived realism in a user study.

We aim at an environment that completely immerses patients, in order to forget reality, be consumed by a virtual, friendly world that allows interactions and explorations. The main research question therefore is, whether visitors of Catharsis Island indeed are immersed and experience the psychological phenomenon called *presence*, concerning the physicality of the world.

2 Virtual Reality in Psychology

The usage of VR in experiments has been of great interest to psychologists and while celebrated for the sheer endless possibilities of immersing a subject into any environment and being able to perform virtually any experiment without (physical) harm to the subject, it has also been scrutinized for often creating poorly designed and potentially ecologically invalid environments [8]. When used in a therapeutical setting, in the past, VR has been quite popular for both *exposure therapy* and *relaxation therapy*, which are discussed in the following.

Exposure therapy is a highly effective method for treating anxiety disorders [7]. The patient is systematically and repeatedly presented with a feared or avoided stimulus (such as spiders or speaking in front of a large audience) [6]. In the real world it can often be difficult to create a scenario in which the patient can be exposed to the triggering cue [6]. Consider for example a room full of spiders or a recreation of a roadside ambush. This is where Virtual Reality can be a solution, since in VR such exposures can be simulated. In this context, *in vivo* means that the exposure therapy is performed in a real setting, while *in virtuo* or Virtual Reality Exposure Therapy (VRET) refers to therapy performed in a simulated VR environment. VRET can be more cost effective when compared to *in vivo* methods when it comes to scenarios that are difficult to reproduce in reality over and over again. Even though about 30% of patients turn down exposure therapy once it is explained to them over 80% express a preference for VRET over *in vivo* [6]. While VRET is widely celebrated as tool that solves many problems with *in vivo* exposure therapy, presenting it as a safe, tailor-made experience with, greater control for the therapist, [8] shows that there are still many fundamental issues with the approach to creating such scenarios with concerns regarding their ecological validity. Ramirez argues that VR-experiments lacking in *perspectival-fidelity* and *context realism* often fail to accurately model situation-related features thus increasing the risk of being ecologically invalid or at least questionable. He proposes an *equivalency principle* which states that VR application be held to the same ethical standards as non VR experiments [8].

2.1 Relaxation Therapy

Stress generally arises when current challenges exceed available coping potential. For over-challenged children and adolescents stress can have a detrimental effect on the development of adequate coping strategies [1]. Due to [5] three major categories of stressors for children and adolescents are described.

- *Normative stressors* are events that arise from the natural development of a child in its social context, such as expectations from family, society and internal expectation to oneself [1, 5].
- *Critical life events* are events that happen suddenly and can change daily routines requiring readjustment to life circumstances. These can be the death of loved ones, chronic illness, or the parents' divorcing. They are generally sudden and cannot be anticipated [1, 5].

- *Every day problems and expectations* are the small irritations and frustrations dealt with on a daily basis. These can appear daily in a recurring manner and are felt as stronger irritations by children because they often cannot be accepted as impossibilities of life as easily as by adults [1, 5].

Relaxation therapy involves refocusing attention from stressors to something calming and becoming more mindful of one’s body[10]. There are many techniques including:

- *Autogenic relaxation*, in which the patient uses visual imagery and body awareness to control their reaction to stress [10].
- *Progressive muscle relaxation*. In this technique the patient focuses on tensing each muscle group which intends to help become more aware of physical tensions [10].
- *Biofeedback* focuses the patients’ attention towards their body’s reaction to stress via visualization of biosignals [9].
- *Visualization* is a technique in which patients attempt relaxation by mentally visualizing calming places [10].

VR can be an important tool in this context to create the visual and auditive stimuli for the patients.

3 Conquer Catharsis: An Immersive Relaxation Therapy Environment

3.1 Game Concept

The concept of Conquer Catharsis is a virtual reality game connected to a heart rate (HR) sensor in which children and adolescents can have biofeedback presented to them in a more interesting and engaging manner than simply reading numbers off a screen while performing exercises. Additionally the game has to have very high visual fidelity aiming for a high degree of *perspectival-fidelity* and *context realism*. Some of the properties have been defined a priori, including a natural setting in a forest, and using HR as measurement for progress. On this basis more specific requirements were coined together with the psychologists, and a design was created which was subsequently iterated on for several months. Below, the design, technical implementation, and structure of the game are presented.

Being at its core as a gamified relaxation therapy tool, the game has certain requirements it needs to fulfill to properly assist psychologists in their process. Requirements we assessed are as follows:

- The game needs to be inviting to children and allow for engaging interactions, as opposed to initial assumptions made about a therapeutic tool needing to be serious and controlled. It should exhibit unpredictable and life like interactions.

- It should contain a progression system where the player can make progressive changes to the world by completing the therapeutic exercises - later named relaxation events. The play sessions should be short, it should be possible to pause them and resume them later on. This warrants a saving and loading system with player profiles.
- Biometric data gathered from a POLAR HR-Measurement band should be displayed to the therapist with the option to automatically or manually (specifically for the case where a the HR-Measurement device is not available) trigger relaxation events in the game environment.

3.2 Implementation

The software package as a whole is able to receive data from a HR monitor via Bluetooth, process this data and display it to the player (child) in a user friendly and immersing way by rendering an adaptive environment and allowing the supervisor (psychologist) to change simulation parameters in real time as well as record the HR data from the play session. Since Conquer Catharsis is a VR game, Unreal Engine 4 (UE4) was chosen as the core authoring program. A custom version was created which integrated the NVidia VR-Works SDK and NVidia FLEX SDK. For 3D model fix-ups, 3DS Max was used. Gimp 2 was used for texture authoring and editing. TexMaker 2 was used for automatic generation of normal maps or ambient occlusion maps. Quixel's Megascans Bridge was used to import assets from the Megascans Library into UE4. The project was stored in a repository on bitbucket and managed with Source Tree.

During development we found that it was virtually impossible to connect the POLAR HR band directly to the used gaming laptop under MS Windows 10. Thus, to mediate the Bluetooth connection between the POLAR HR band and the VR game, a second-screen app was created. The app is deployed together with the packaged game and runs on the Android operating system. Additionally the game comes with an integrated TPC server that serves as a connection between the app and the game. During the game a QR code can be scanned by any QR code scanning app running on a smartphone. The code contains a url that is generated at runtime and directs the smartphone's browser to the address of the game's local TPC server where the second-screen app can be downloaded. A second QR code can be scanned by the second-screen app and is used to connect the app and the game server. Once the connection is established the app can connect to the POLAR HR band. Then it periodically sends HR data and other control data input by the supervisors to the game.

3.3 Game Design

Design has many facets depending on the discipline examined. In this context design is understood as gameplay design - which is the design of specific gameplay mechanics - and level design which is the design of the play-space. Since most game have some sort of play-space that needs to be defined and some sort of rule-set, the fields of gameplay and level design are the most prominently perceived

by players. Because the game is played under supervision, all the interaction possibilities and traversable locations can be explained to the player by the supervisor (psychologist) if the design fails to communicate something properly (given that making all options easily understandable is goal of the design). This made it much easier to leave gaps in the design, or try things that might not work well, as all interactions could be explained by a supervisor during play.

The core gameplay of Conquer Catharsis consists of teleporting and relaxing. Additionally the player can grab or push certain predefined objects and get navigation help. For each motion controller a virtual hand is displayed in the game to increase the *perspectival fidelity* effect. Displaying the motion controllers as 3D models in the virtual world is also a popular method. In this tour though *abstract* hand models - as opposed to *realistic* hand, or 3D models of the motion controllers - were chosen to disconnect the player from the real world and not cause an *uncanny valley* effect if the hands felt too lifelike [11]. The gameplay is split into two types: structured **relaxation events** and **free exploration passages**.

- *Relaxation events* are small areas marked as stone circles, meant to be visually segregated from the rest of the environment. Upon entry the event activates, displaying a wind around the player directing their attention towards the point of interest (this can be a waterfall that will become visible, or a tree that turns green) and the sounds of the environment are reduced in volume to exclude distractions. The player can then start the event by pushing down on a large stone button in front of them. When an event starts, it periodically queries the HR-Monitor connection component for the current heart rate, Baseline, Threshold, and Threshold time. All the values except for the heart rate can be configured in the companion app and adjusted in real time.
- *Heart rate* is the current heart rate of the player as reported by the HR device.
- *Baseline* is the base heart rate of the player recorded over a certain interval.
- *Threshold* is the target heart rate the player must be under in order to complete the event.
- *Threshold time* is the amount of time the heart rate must be under the threshold heart rate in order to complete the event.

The relaxation event uses these values to drive changes in the world by calculating progress as a linear interpolation of the heart rate between the baseline and the threshold, where when the heart rate equals the baseline, progress is 0 and when the heart rate equals the threshold, progress is 1 (see Fig. 1-Fig. 3). This is then passed to an event handler component that implements case specific logic for changing the world (see Fig. 4).

Exploration passages are the less structured free play aspects of the game. They are designed both as passages to the next event, usually with a path or landmark visible, and as areas where more paidia-like free play can take place [3]. Toys in forms of swords, shields, sticks and FLEX enabled plants and balls are



Fig. 1. Forest bloom event at progress 0. **Fig. 2.** Forest bloom event at progress 0.5.



Fig. 3. Forest bloom event at progress 1.

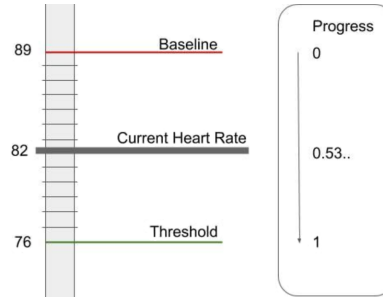


Fig. 4. Progress handler.

placed here, as well as obstacles like rocks and tree stumps to break up the linear structure and encourage the intended free play. During game play, the player can use the game controllers to carry out the following interaction types:

- *Teleportation* locomotion is one of the most important tasks in 3D VR-Games [2]. HMD positional tracking within the physical - real world - play-space is managed by the Unreal Engine 4 API. However, once the player is required to travel larger distances than the physical play-space, different locomotion techniques need to be used [2]. Unreal Engine 4s VR template already includes a basic teleportation mechanic that requires the player to aim a beam at the desired arrival location. Using this template as a starting point we built a system that gives feedback as to where navigation is allowed, thus restricting teleportation over larger distances.

One of the challenges of creating large spaces in VR - apart from managing performance - is comfortable locomotion. Using a teleportation system that allows the player to advance a few meters per interaction can be tiring when the distance between points of interest is in the dimension of hundreds of meters. Since the structure of the island is built around small points of interest with long exploration paths between them, a larger teleportation distance was chosen.

- *Grabbing* is only needed during the free play aspects and serves the purpose of picking up objects or manipulating FLEX enabled objects, like branches.

- *Navigation help* supports the supervisor in guiding the player through the tour. It is also meant to feel like fun and magic. When the face button of the left controller is pressed, a visual path is overlaid on the world to show a path towards the nearest incomplete event. Additionally a ghostly rabbit emerges from the hand and runs along the path. Although the game is played under supervision we found that this navigation help might be necessary to better help the player understand the supervisors guidance.
- *Relaxation* is a gameplay mechanic that is directly driven by the player but cannot be manipulated or mastered by better understanding the implementation of the mechanic. Consider a Jump and Run game where the player moves from platform to platform by timing their jumps correctly. The player can achieve mastery over the gameplay mechanic of jumping by practicing and learning the underlying mechanics that the game designer defined. But with biosignals driving the gameplay, the player’s body becomes the focus of mastery.

Level Design The playable area consists of one large persistent level (or world) with several sub-levels for organizational purposes and streaming levels for optimization purposes. The separation of the levels only partially overlaps with the conceptual grouping of game areas. In each thematic area (e.g. Forest, Cave, Ruin, etc.) there exists at least one relaxation event that controls some part of its environment.

3.4 Catharsis Island

The decision to create an island as the stage for the relaxation adventure was made after several iterations on the planed scenarios and diverged greatly from the original idea. Ultimately it is a visual expression of the game-play and high-level level design. Creating an island came with its own set of new challenges that also changed the requirements towards the project structure in regards to performance. During brainstorming and assessment with the psychologists from the Medical University of Vienna we came up with many HR-Events of varying complexity and spacial requirements (e.g. one required a large amount of space to move while another only needed the player to stand still). In combination with the requirement to have the player have an overview of their goals and successfully completed relaxation events, we designed a progression scheme with vertically arranged *tiers* and horizontally arranged *zones* (see Fig. 5 showing them as a level graph), where each stage could overlook all the its zones and HR-events.

Naturally the meta design gave way to individual requirements and artistic choices in the execution. During development, zones where removed, changing some of the vertical and horizontal arrangements originally laid out. Choosing to visually execute on the concept with an island originated from the artistic desire to have some kind of large body of water combined with the meta design of ascending levels which was designed as a tree covered mountain This processresulted in the following zones:

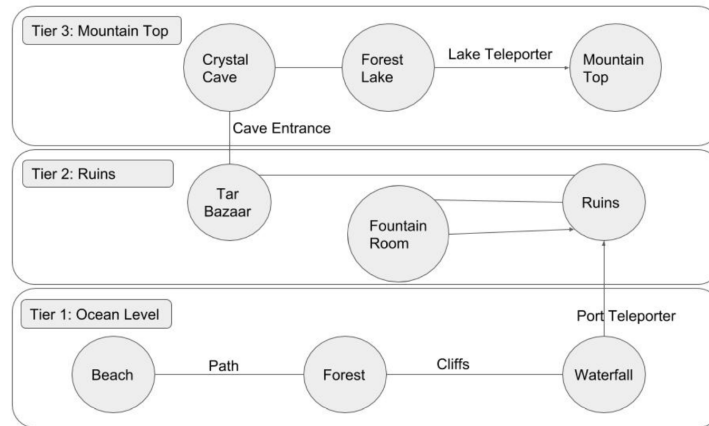


Fig. 5. Level Graph



Fig. 6. View from the starting point. Fig. 7. View of the Island from the Beach.

- **Zone 1: Beach.** Being the starting area means that the first experiences within the game would be made here, thus the zone also acts as a kind of tutorial. This results in the requirement that right at the beginning, players need to have a clear overview of where they are and where they have to go. When the tour starts for the first time, the player is placed on the beach oriented towards the forest - assuming that the VR-HMD in the real world is oriented in its default forward direction (see Fig. 6). A path leads towards the forest with several human made elements such as wooden fences, accentuating the visual cues that try to lead the player into the forest. As the players look straight ahead they can discover the first HR-event. The space around it and on the rocks behind the players define one of the larger open spaces in the game, with the intention of inviting the players to learn the teleportation mechanic, and have much physical space for exploration. Behind the players the ocean separates them from the rest of the island. Several larger landmarks are visible, which are intended to guide the players further into the island (see Fig. 7).
- **Zone 2: Forest.** Apart from a few trees scattered around the island, the forest zone is the only remnant of the originally planned forest that was sup-

posed to be the entire experience. The forest is situated on an elevated plateau above the beach and is reached by a dirt path that leads up the cliffs. Once in the forest the path forks into two directions, one marked with fences and a clear opening in the undergrowth leads to a clearing where the “animal petting” relaxation event awaits (see Fig. 8).



Fig. 8. Forest clearing with deer.



Fig. 9. View of the ocean from the cliffs.

- **Zone 3: Cliffs.** The cliffs are a purely explorational zone. Here the player is challenged to teleport from platform to platform over the water and experience being high up on a windy cliff. Between the cliff rocks ropes are spanned with flags that flutter in the wind to support the atmosphere (Figs. 9 and 10).



Fig. 10. Top view of the cliffs.

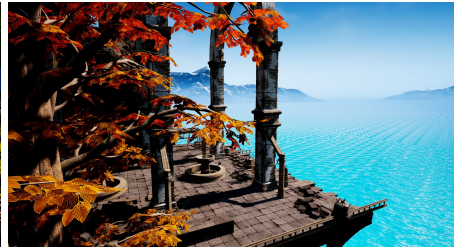


Fig. 11. Throne Room Overview

- **Zone 5: Waterfall.** In its initial state the waterfall is not visible, but by relaxing in the relaxation event the player is able to gradually make it appear and flow again.
- **Zone 6: Port.** The port is the first area the player encounters human made structures. An overgrown ruin with partially intact elements surrounded by trees and water presents itself to the player. From here a teleporter can be taken up to the main ruin on the mountain.
- **Zone 7: Ruins.** The ruins are designed as an exploration area that tries to be less linear than the rest of the game. There are many more side paths and hidden areas for discovery (see Fig. 11).

Thematically the ruins are meant as a solidification of a past human presence on the island, layered on top of the even older “elder ruins”.

- **Zone 8: Ruins: Fountain Room.** The fountain room can be entered by completing an HR-event that opens the door to the zone.
- **Zone 9: Ruins: Tar Bazaar.** The basic concept for this zone came from having some form of stress inducing event that distracted the player from concentrating purely on relaxing. The idea was to have a constant stream of stimuli coming at the player while they tried to relax. During development the spacial and thematic structure of the area where the “clean-up event” was supposed to take place was changed. Visually it became a sunken city square in a tar pit (hence the name “Tar Bazaar”). In this “clean-up event”, the player has to fish garbage out of a tar pit while relaxing. The player has “wind vacuums” attached to their hands which suck the garbage out of the tar at a distance. As the player relaxes the flow of trash becomes less and the tar pit slowly turns into a lake. Upon completion waterfalls start flowing again and the player can proceed towards the cave.
- **Zone 10: Cave.** The cave is accessed through a door that is opened with a relaxation event and is split into two parts: the cave ruins and the crystal cave. The cave ruins are the first part of the cave serving as a transition zone to the crystal cave. Thematically it is part of an underground passageway through the mountain, build by the humans who also build the ruins. To give a sense of size beyond the limits of the actual physical space the level inhabits, a sky dome with a projection of a larger cave was used as a background. Objects such as hills and castle ruins were placed at quickly decreasing scales towards the back of the cave to increase the sense of depth.
- **Zone 11: Crystal Cave** The almost completely unlit crystal cave forms the rear part of the cave. Here the player lights up glowing crystals mounted on the walls in a relaxation event. The intent was to have to player feel in control of a dark place with limited vision and make an otherwise unwelcoming place seem magical.
- **Zone 12: Forest Lake.** After exiting the cave the player passes through a patch of conifer trees to the forest lake. Here a relaxation event allows the player to lift a sunken bridge out of the water allowing the player to pass to a platform with a teleporter in the center of the lake. This is the last relaxation event and is rewarded with the teleporter to the top of the mountain.
- **Zone 13: Mountain Top.** From the mountain top area the player is able to see the entire island and through the light beams each completed relaxation event emits see all their achievements.

4 User Study and Results

To evaluate the sense of presence experienced in the game a user study was conducted. 20 People of varying ages, genders and VR experience were given 15 minutes to play in the forest and then asked to fill out a questionnaire based on the IGroup Presence Questionnaire (IPQ) [4]. The IPQ evaluates 3 main categories:

- Spatial Presence, which is the sense of being in the Virtual Environment.
- Involvement - how much attention the user devoted to the virtual environment.
- Experienced Realism - the subjective realism of the virtual environment.

Additionally there is one item to assess the general “sense of being there”. After

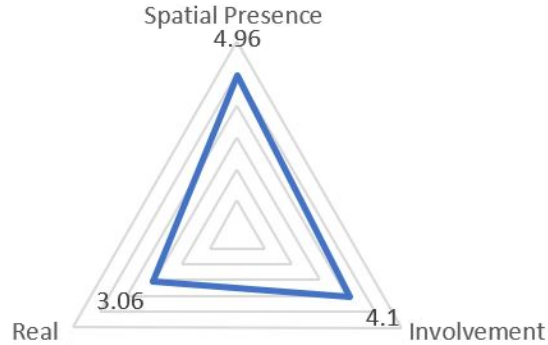


Fig. 12. Questionnaire results

evaluating the questionnaires the data was plotted in a spider chart (see Fig. 12). We find users had a high sense of being spatially present, which in part we attribute to the good tracking of the HTC Vive and the high frame rate.

Experienced realism achieved a comparatively high rating. Deeper analysis showed that most users did not find the actually setting realistic but experienced the place as realistic. Some items of the questionnaire directly tested if the user perceived the tour as realistic when compared to their real world. We find this to be problematic for experiences that do not seek to recreate real world places. This would be more suited to experiences such as virtual house viewings but not virtual fantasy places. We conclude that people can experience a fantasy ruin as realistic and feel present in that space, while very well knowing that this space does not exist anywhere else in their real world experience.

5 Conclusion

Creating a computer game is not a trivial task. In this paper we describe the processes involved in the development of Conquer Catharsis, starting with the design and planning, then how the assets were prepared and what technical decisions were made and also covering some of the ethical considerations made. In a user study we evaluated how present a player feels in the tour. The environment will serve as the basis of further research into the topic of biofeedback relaxation therapy.

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