Virtual and Augmented Reality Therapy Framework for Phobia Treatment

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Abstract. Phobias are a common type of anxiety disorder that affects a great number of people. Treating phobias is not always straightforward and require a significant effort from both the patient and the therapist. In recent years, Virtual Reality Exposure Therapy and Augmented Reality Exposure Therapy have emerged to help in phobia treatments by using virtual content. However, most available systems are not free and require expensive hardware. In this paper, we present a free and open-source framework for phobia treatment, designed for both the therapist and the patient. A Virtual Reality scenario for acrophobia (fear of heights) and an Augmented Reality scenario for arachnophobia were developed for validation.

Keywords: Phobia Treatment, Virtual Reality Exposure Therapy, Augmented Reality Exposure Therapy, Android, Unity3d, Human Computer Interaction.

1 Introduction

Phobias are one of the most common types of anxiety disorders, affecting a significant number of people around the world [1]. One of the most commonly used methods for phobia treatment is exposure therapy [2], [3]. The advance of technology contributed to the generation of more Virtual Reality (VR) and Augmented Reality (AR) audiovisual content than ever before. Because of that, Virtual Reality Exposure Therapy (VRET) and Augmented Reality Exposure Therapy (ARET) emerged as novel alternatives for phobia treatment. They are innovative tools for conducting exposure therapy by which the users can be systematically exposed to specific feared stimuli in a safest environment.

Many research studies and clinical experiments have shown that VR and AR can be used as a highly efficient treatment for obsessive-compulsive, anxiety, and phobic disorders [4], [5], [6], [7].

Although these studies presented many different approaches, they have only focused in very specific applications for particular scenarios. For this reason, we consider that a general approach is necessary.

On this paper, we present an open-source and free framework to facilitate the implementation of VRET and ARET scenarios for phobia treatment. This work supports the implementation of affordable alternatives for phobia treatment by using low-cost VR and AR systems.

This paper is organized as follows. The next two sections discuss the efficiency of VR and AR for phobia treatment and the systems and prototypes presented in the literature. Section 4 details the proposed system. In Section 5 a detailed description of the framework's architecture is presented. Then, two study cases developed for this work are presented in Section 6. Finally, the last section outlines the conclusions and future work.

2 Background

VR is a technology that generates a complete Virtual Environment (VE) by replacing the existing physical environment and providing users with new ways of interaction and navigation. In contrast to VR, AR is a technology that uses virtual elements to augment the existing environment. While AR users maintain their sense of presence in the real world, VR users are completely immersed in the virtual world [8].

The literature provides strong support for the effectiveness of exposure therapy for anxiety disorders [9]. VR and AR can provide a high level of presence and immersion within the exposure, which may allow for higher engagement and fewer distractions than other methods. They also provide the ability to stimulate multiple senses during the exposure, through tailoring the visual and auditory stimuli, arousing the patient's sense of touch, or by adding relevant smells. The dynamic interaction between the patient and the VE, and the ability to engage multiple senses, facilitates a sense of truly "being there". Indeed, a previous study discovered that adding additional types of sensory input within VR, such as olfactory and auditory cues, increase the participant's sense of presence and memory [10].

VRET is a well-established technique to treat psychological disorders such as phobias. In a published meta-analysis on the efficacy of VRET on different phobias, the authors concluded that real life interventions were not significantly more effective than VRET [11].

AR also has great potential for phobia treatment because virtual objects are shown as if they belong to the real world. Hence, patients can see their own body and interact with the virtual objects in a more natural fashion [12]. Despite this, AR systems for phobia treatment are not as common as VR systems.

A more recent meta-analysis discussed the effects of VR interventions for anxiety disorders [13]. They considered disorders such as social phobia, panic disorder with or without agoraphobia, and post-traumatic stress disorder. The authors reported no overall difference between VRET and cognitive behavior interventions on behavioral assessments and post-treatment.

Other studies have shown the benefits of ARET for insect phobia treatment. Chicchi et al. [5] provide a review of recent studies on the evaluation and treatment of psychological disorders. It details how this technology can be used in the psychology field as an efficient tool for phobia therapy.

Botella et al. [6] describe their AR system and how it is used to activate anxiety in participants who suffer cockroach or spider phobia. They also discuss the extent to which participants considered the experience as real. The study showed the advantages of using AR in cockroach phobia treatment as all participants improved significantly in all outcome measures after the treatment.

3 Previous Works

The literature presents many VR and AR systems specifically designed for phobia treatment [14], [7], [15], [16], [17]. Most of them usually consist of two main components. First, an application for the patient to experience a particular scenario. Second, an application for the therapist to configure the scenario for the patient. The therapist's application may contain more features such as live video streaming of the patient's view, stimuli tuning, or patient's data storage.

PsiusVR [14] is a paid VR system that offers a real-time streaming of the patients' view, biofeedback sensor for patient monitoring, and automatically-generated reports. It consists of a web application running on the therapist computer, and a mobile VR application that runs on a smartphone. The patients must use a VR headset to run the smartphone application. The system presents many scenarios for different phobia treatments, such as acrophobia, agoraphobia, claustrophobia, amaxophobia, fear of flying, needles, animals, and public speaking.

NeuroVR [7] is a free and open-source VR platform. It consists of two main components, the Editor and the Player. The Editor is used to visually create scenarios without requiring programming skills. The user can choose from a database of 2D and 3D objects, placing them into a pre-designed virtual scenario. The Player is used to navigate and interact with the VEs created. The system can be visualized on both a regular PC and a head-mounted display (HMD). However, the use of a smartphone as HMD is not supported.

PhoVR [18] is a VRET system developed in Unity3D to give patients a presence in a VE to face their fears. This system focuses on arachnophobia, acrophobia and agoraphobia. By using the Microsoft Kinect, the patients are able to move and see their bodies in the visualization. However, that visualization is only previewed on desktop PC, and HMDs are not supported. Furthermore, an internet connection is required to communicate the patient and the clinician.

Virtually Better [15] is a company that develops VR applications for many disorders such as phobias, post-traumatic stress disorder (PTSD), and stress and pain management. They developed applications that consist of two parts, a mobile application which runs on iPhone and Android, and a desktop application for Windows and MacOS. This system offers scenarios to treat the fear of flying, acrophobia (elevator and bridges experiences), fear of public speaking, and fear of storms. In addition, they developed a system to conducting exposure therapy in two war-zone virtual environments: Iraq and Afghanistan; and a system for treating addictions such as alcohol and tobacco.

Some studies also applied VRETs to other types of phobias. In [16] they use a VRET to treat dental phobia. Their system contains a desktop application for the therapist to control the stimuli, and a VR application for the patient. The system uses an Oculus Rift HMD to present the VE to the patients. To enhance the immersion of the VE, the typical smell of a dental clinic was introduced. Their results suggest that in order to establish the efficacy of VRET in the treatment of dental anxiety, more carefully controlled trials are required.

Other studies take advantage of the fusion between the real and virtual world that AR provides. Fatharany et al. [19] present a design and implementation of an AR application for cockroach phobia therapy. This system was developed using Unity3D and the OpenCVForUnity library. It only runs on desktop PC by using an external camera. Thus, the patients have to look at the computer screen to be immersed in the augmented scenario.

Another AR system for treating spiders and cockroaches phobias is presented in [17]. That system uses ARToolKit and VR Modeling Language (VRML) to incorporate AR virtual objects. The patient must wear a HMD and the therapist has a live video streaming of the patient's view. To make this possible, they used a creative NX-Ultra camera attached to the HMD.

Corbett et al. [12] developed an interactive AR system that contains a 3D representation of the real environment and the patient's body. Hence, a virtual spider that is presented to the patient can move and react to the real environment in a very realistic manner. Furthermore, the spider can walk up, around, or behind real objects and can be touched, carried, and occluded by the patient. This system uses the Microsoft Kinect to track the patient's body and movements.

Most of the mentioned systems are not free or open-source. Whenever a new scenario to the treat a patient is needed, a new system must be implemented from scratch. On the other hand, not many therapy systems support low-cost VR or AR. The therapist should therefore invest a lot of money in a fully equipped system. To the best of our knowledge, there is no open-source and free framework for the implementation of VRET and ARET scenarios for phobia treatment.

4 Proposed System

In this study, we present a VRET and ARET open-source and free framework for phobia treatment. This framework was developed to be easily customized, allowing the creation of VR and AR environments using the cross-platform game engine Unity3D.

The system consists of two main components. The desktop application that is used by the therapist as a control and configuration tool, and the mobile application that is used by the patients to get immersed in the virtual scenarios.

The framework is currently available on GitHub, and the detailed guidelines for the implementation can be found in the repository website. The framework architecture is presented next.

5 Framework's Architecture

In order to create a new scenario for phobia treatment, some components must be implemented. Those components are described next.

5.1 Desktop Application

The desktop application is used by the therapist as a control and configuration tool. By using the desktop application the therapist can establish a connection with more than one patient at the same time. Once the connection is established, the desktop application can communicate to the mobile application to manipulate the scene and to control the exposure levels.

To provide the therapist with the possibility to see what the patient is watching in real-time, a video streaming feature was implemented. Hence, the therapist can see and better understand what the patient is experiencing at any time.

Finally, the desktop application is used to select among the different available scenarios. This provides the possibility to have more than one phobia scene in the same desktop application. Once a scenario is selected, the application loads and shows on the screen the necessary User Interface (UI) elements to manipulate the features of that particular scenario.

5.2 Mobile Application

The mobile application is used by the patients to get immersed in the VR and AR scenarios. The application runs on a mobile phone inside a low-cost VR headset. In a VR scenario, patients feel fully surrounded by the virtual world. They can turn their head and see the virtual world as if they were there. On the other hand, in an AR scenario, patients see the real world that is captured by the mobile phone's camera. In order to present the virtual objects, a regular AR marker is used. When the application detects that marker, a virtual object is displayed on it. Thereby, when patients see the marker through the application, it provides the sensation that the virtual objects belong to the real world. It is important to notice that patients are experiencing the AR scenario through a headset with their full field of view. This improves the immersion level compared to the typical AR applications, where the mobile phone is on the users' hands.

The mobile application contains every possible scenario that can be chosen in the desktop application. A Camera Component is used to detect QR codes for connection, to detect the AR marker, and to record what the patient is watching for real-time video streaming. The mobile application also contains a Network Manager Component to manage the connection, and a Scene Manager Component to control the events execution. These components are explained next in more detail.

5.3 Network Manager Component

A communication between the desktop application and the mobile application must be established. As the system is designed to be used by more than one patient at the same time, a client-server model was implemented. The desktop application acts as a server and the mobile application must know the desktop PC local IP address. For this reason, the desktop PC and the mobile phone must be connected to the same local network.

Instead of manually typing the IP address, a more practical method was implemented. The local IP address of the desktop application is encoded in a QR code that is presented on the screen. Then, when the mobile application starts, this QR code must be scanned, automatically establishing the connection.

The Network Manager Component manages the connection between the desktop PC and the smartphone. Once the therapist selects a phobia scenario on the Desktop application, the Network Manager Component is instantiated and awaits for the phone connection. On the phone side, the Network Manager Component is already created and connects to the Desktop application as mentioned. Once the connection has been established, the Scene Manager Component is created on both the desktop and mobile application.

5.4 Scene Manager Component

Once the connection has been established, this component handles the messages exchange between the desktop and mobile applications. The system uses Remote Procedure Calls (RPCs) to send and receive specific messages through the network. On the desktop application, the Scene Manager Component contains the method definitions to perform the RPCs that will be executed on the mobile system. When the therapist selects one of the available actions on the UI, a specific RPC is performed.

On the other hand, for the RPCs to work properly, the Scene Manager Component implemented on the mobile application must have the same method definitions as the desktop application. These methods implement actions to modify the scene according to the selected event on the desktop application.

6 Case Study

In order to test the framework, two phobia treatment scenarios were developed. First, we developed a VR scenario for acrophobia (fear of heights), a disorder that affects approximately 5% of the general population [20] and is one of the most common phobias treated by using VR [21, 22]. Treating this phobia without VR can be a very complicated and dangerous process since it requires the patient to be exposed to different heights.

Then, we developed an AR scenario for arachnophobia (fear of spiders), one of the most common animal phobias, that affects approximately 3.5-6.1% of the general population [23]. The use of AR for animal phobia treatment has become very popular as it creates the sensation of being in front of the animal. Also, the exposure to real animals can be very complicated, expensive, and mostly, very dangerous.

This implementation was tested on a desktop computer running Windows 10 and a smartphone running Android 6.1. The implemented scenarios are described next, and the source code and the executable versions are available on GitHub.

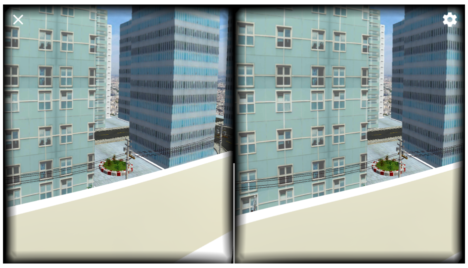

Fig. 1. Android Application for acrophobia treatment. The patient is approaching the balcony's edge, with walls activated.

Fig. 2. Desktop Application. UI Control Scene for acrophobia treatment.

6.1 Acrophobia Scenario

In the proposed VR scenario for acrophobia treatment, the patient is located in a room with a balcony inside a building in the middle of a city. Patients are able to walk inside the VE by using a wireless joystick. Thus, they can approach the edge of the balcony at their own pace, as depicted in Figure 1.

By using the desktop application, the therapist can modify the height of the building, i.e. the floor where the patient is located. Also, the therapist can hide or show the floor and walls of the balcony. Figure 2 shows the UI in which the therapist can progressively increase the exposure levels, avoiding abrupt jumps.

6.2 Arachnophobia Scenario

An AR scenario was developed for arachnophobia treatment. It is important to remember that the patient is wearing a low-cost VR headset but, unlike in VR, in this AR scenario the patients see the real world that is captured by the mobile phone's camera. As shown in Figure 3, when the patient looks at a specific AR marker that is over the table, a 3D virtual spider appears. The spider provides the illusion of being walking over the table.

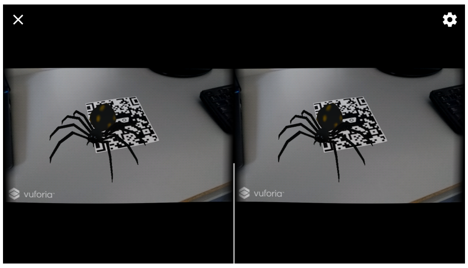

Fig. 3. Android Application for arachnophobia treatment. The patient can see a virtual spider walking over the table.

By using the desktop application, the therapist can change the spider's size, make it walk, and create additional spiders. As shown in Figure 4, the therapist can progressively increase the exposure levels.

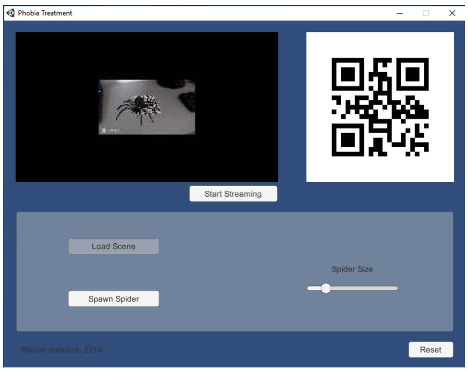

Fig. 4. Desktop Application. UI Control Scene for arachnophobia treatment.

7 Conclusions

VR and AR technology provides the opportunity to include aspects of feared stimuli that could otherwise be too expensive or impractical. Additionally, it allows the therapist to control every aspect of the exposure. This level of control also allows for repetition exposures which may not be possible in real life.

Even though VRET and ARET have existed for many years, the literature presents different systems and applications that were designed only for one specific purpose. On the other hand, the available commercial software is not free and may require expensive hardware.

In this paper, we have presented a VR and AR framework for the creation and customization of VEs for phobia treatment. This framework is free and open-source and is designed to be used with low-cost VR and AR devices. By using this framework, the applications for both the therapist and the patients are created.

In order to show the potential of the framework, two phobia scenarios were developed addressing acrophobia and arachnophobia treatments. These prototype scenarios showed the framework's flexibility in terms of the immersion and extensibility. Informal tests were performed with volunteers that collaborated by giving feedback about the immersion sensation they felt. Their comments helped adjusting the scenarios' features as well as setting the exposure levels behaviors. Even though the visual quality produced by a smartphone and a low-cost VR headset is low compared to high-end VR devices, all the participants indicated an appropriate sensation of immersion. Also, most of the volunteers considered that the implemented behaviors were suitable to increase the exposure levels.

The implementation of the case studies and the test suggested the framework's efficiency. However, some limitations are worth noting. Although the system was tested by participants, formal tests were not performed. Future work should therefore test the implemented scenarios in real situations with real patients, and with the collaboration of experienced therapists or psychologists. This would corroborate the efficacy of the developed system and would provide new ways of improvement. Also, more studies are needed in order to test the performance of VRET and ARET compared to standard exposure therapy. Being an open-source system, we expect the VR research community to collaborate and improve it by offering new alternatives, not only for phobia treatments, but also for others psychological disorders that can be faced with this novel technology.

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