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VR Acrophobia Treatment – Development of Customizable Acrophobia Inducing Scenarios

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Abstract

Specific phobias are among the most common mental diseases, affecting the lives of millions of people. Yet, many cases remain untreated and even undiagnosed, partly due to entry barriers such as waiting times and inconvenience of therapy. To improve the therapeutic options and convenience for the treatment of specific phobias, we implemented a virtual reality application for treating acrophobia (fear of heights) with in-virtuo exposure therapy. Our concept is based on principles from psychology and interaction design. This concept is then implemented using the game engine Unity and Oculus Rift headset as a target device for VR display. Our application has a wide range of customization options, which enables it to be personalized to individual patients. In addition, a number of motivational methods are integrated, which are intended to increase patient motivation, as motivation is essential for a successful therapy.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality;*** *Interactive systems and tools; Visualization;* • ***Applied computing*** → ***Health informatics;***

1. Introduction

Anxiety disorders, such as generalized anxiety disorder, specific phobias, and posttraumatic stress disorder (PTSD) are among the most common mental disorders in modern society. While many suffer from only mild forms of these conditions, each has the potential to severely impair normal functioning in everyday life, posing a threat to the productivity and happiness of those affected [PR08]. *Specific phobias*, a common type of anxiety disorder in which fear and anxiety are caused by specific objects or situations, affect approximately 15 % of Germany's adult population [JHS*14]. Some of the most common specific phobias are arachnophobia (fear of spiders) and acrophobia (fear of heights) [SP10]. Persons affected by phobias tend to avoid feared stimuli and experience immediate distress when unable to do so [MD14]. It is estimated that less than 20 % of those with an anxiety disorder seek treatment, even though many may benefit from successful therapy [AL07]. A typical behavior in anxiety disorders is the conscious avoidance of the situations that trigger anxiety. However, safety and avoidance behaviour can also be certain types of behaviour that are carried out during anxiety situations in order to distract from the fear or to suppress it. These behaviors are internalized by phobics until they become second nature and resistant to change. For those who seek therapeutic support, exposure therapy (ET) is commonly used, a treatment approach where the patients are repeatedly confronted with their fear. A virtual reality exposure therapy (VRET) application can improve the accessibility of ET for patients. Hereby, transferring the mechanisms of real-life ET is essential to create an effective application. This is the great strength of VRET, because any real situation can be simulated and the virtual environment (VE) can also be extended by elements that would not be feasible in the real world. A main challenge for a behavioral therapist using ET is to motivate patients to attend therapy regularly. Since a double-digit percentage of the whole population suffers from at least mild anxiety disorder, the potential demand for one-on-one treatment exceeds the capacity of therapists. The use of VRET also offers the possibility of treating patients with less effort and, thus, more cost-effectively, since no travel time to the corresponding locations is necessary.

Our VR acrophobia treatment system, developed in the Master thesis by Illner [Ill18], includes the following:

- an immersive VR environment using a head-mounted display (HMD) with two diverse scenarios and different motivational elements and
- a high degree of customization options to personalize to the needs of each individual patient.

2. Background and Related Work

ET is considered the most effective treatment for anxiety disorders based on empirical data [ADW11, KT11]. It involves identifying the anxiety-inducing stimuli or situations and subsequently confronting patients with them in a controlled and safe environment.

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During the confrontation, the therapist helps the patient to stay calm and in control of their sensation of fear. Patients are required to willingly endure feelings of anxiety and suppress acquired avoidance and safety behaviors. Over time, clients become more comfortable and regain control of their fear perception.

VRET There has been research on the treatment of specific phobias with VRET for at least 20 years. A meta analysis publication examine its efficacy [PE08]. VR is used to create immersive experiences and natural interaction within computer-generated environments using special display and tracking devices. VRET uses these capabilities of VR to aid ET [MKBKR17]. One reason for this continuing interest in the approach is that there are some evident limits and downsides to imaginal (patient is asked to imagine feared situations) as well as in-vivo exposure. While research indicates that in-vivo is the most effective variant of ET, in many cases using it can be inconvenient or impossible [ADW11]. Using a VE, almost any situation required may be replicated and even adjusted on the fly without the need to leave the therapist's office [MKBKR17]. In-virtuo exposure has been shown to create similar physiological reactions to equivalent real environments and in several cases has comparable efficacy to in-vivo exposure [KEB*04]. In addition, realistic virtual situations can also be extended by elements that are difficult or impossible to realize in the real world. Parsons and Rizzo [PR08] cite multiple studies demonstrating that VRET can drastically reduce anxiety symptoms over relatively short amounts of time, but it should be noted that they considered the sample sizes for some of the referenced studies too small to be deemed reliable. They attest VRET "good potential as a treatment approach for specific phobias". Emmelkamp et al. [Emm13] conclude that VRET is more effective than imaginal exposure. Other authors obtained comparable results for in-vivo and in-virtuo treatment, e.g. [KEB*04]. Krijn et al. [KEB*04] examine two kinds of VR hardware (HMDs, CAVE installations) and found no significant difference in effectiveness between them. Several publications address the importance of the feeling of presence during VRET [KEB*04, Emm02], i.e. the illusion of "being there" must be so strong that participants indeed exhibit fear.

Acrophobia Several publications address acrophobia in particular and demonstrate that it can be successfully treated using VRET [MD14, KEB*04]. A large-scale study conducted by Freeman et al. [FHF*18] used a therapy application with similar goals to those of our work. The study was conducted on long-time acrophobics and they used the developed application around six times in two weeks. Therapy sessions included an initial assessment with an in-VR virtual coach, an animated human-like female agent that was created using motion capturing of a real actor. The virtual coach in the software initially explained mechanisms of ET, including how safety behaviors have to be overcome. Interestingly, "the treatment was not designed as ET (i.e. participants were not asked to remain in situations until anxiety was reduced) but as repeated behavior element tests". Our application consists of two scenarios and is intended to offer high adaptability so that the therapist can adapt it to the needs of individual patients. In addition, we present motivational elements that should encourage repeated willingness to confront their own fears, as a prerequisite for a successful therapy.

3. System

This section describes the VE we created based on the current literature and discussions with two experienced therapists who treat people with anxiety disorders frequently. We describe the constructed scenarios, discuss the locomotion system, explain the anxiety reporting system and the used motivational elements.

3.1. Scenarios

How to design the exposure elements is of central importance for the VRET application. In the literature of acrophobia treatment, bridges, towers, staircases, and rooftops were often mentioned as environments for height exposure in in-vivo as well as in-virtuo environments [CWHW09, JP09, HKM*95]. Virtual bridges and towers can, by scaling or repetition of elements, easily be adjusted and extended in a 3D application. This makes them suitable to *gradually* change levels of exposure. This also applies to staircases and parking garages. The transparency of floors and walls as well as the availability and height of railings can be controlled in a VR software. A real-world rope bridge induces anxiety even in individuals with normal levels of anxiety and serves as an example of how the impression of (in-)stability can influence anxiety. On the basis of these considerations, a tutorial level and two scenarios were designed.

3.1.1. Tutorial Scenario

An initial area was designed as the starting point for every ET session. It is intended to create a safe atmosphere, but also to provide a glimpse into the VE and the exposure tasks ahead (see Figure 1). It is also the area where a tutorial takes place.

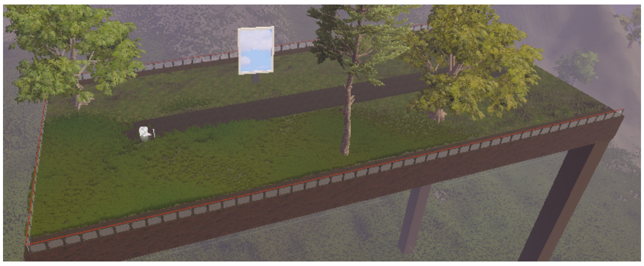

Figure 1: *VE of the application where the tutorial takes place.*

3.1.2. Bridge Scenario

In the *Bridge Scenario* the user is asked to cross a number of platforms connected by bridges, with each bridge increasing the perceived threat of falling down and exposure to height (see Figure 3). These bridges have different characteristics so that they represent different degrees of difficulty:

- availability of railings and the narrowness of the bridge,
- perceived stability of the bridge, for example by using a rope bridge or placing objects on it that move due to physics,
- using holes in the bridge or visualizing it translucent to make the depth below it more prominent, and
- varying the length of the bridge together with the distance between platforms.

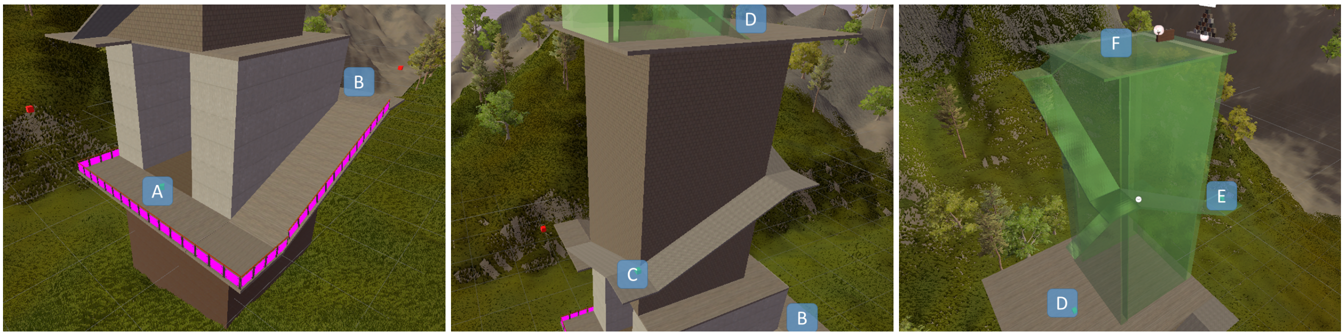

Figure 2: *Tower Scenario with the locations of the anxiety rating requests.*

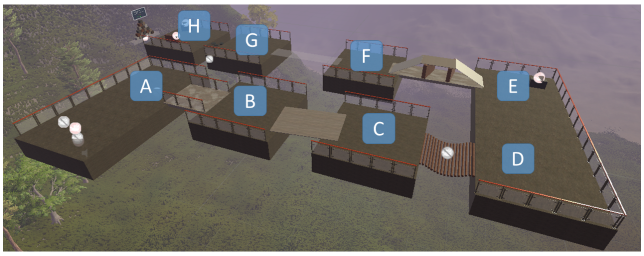

Figure 3: *Bridge Scenario with the locations of the anxiety rating requests.*

Table 1: *Characteristics of the six bridges*

Bridge	Characteristic
1	solid ground, railings
2	solid ground, no railings
3	unstable ground, no railings
4	unstable ground, elements may fall down
5	solid ground, transparent, narrow
6	solid ground, pillars with spacing

Using all of these characteristics, we created six different bridges (see Table 1). We sorted the bridges according to our personal assessment of difficulty. However, the uniqueness of each individual case of acrophobia makes it unlikely that varying all these aspects between the bridges will yield a strict order to escalate anxiety for graded exposure. Any given bridge may be rated differently in terms of anxiety levels by different individuals. Therefore, there will not be a standardized order of the bridges, resulting in an increasing degree of difficulty for all patients. Some bridges might represent an especially tough challenge for a certain patient. But if all the above aspects of the bridges are varied, it is likely that a later bridge will appear easier from their perspective, which may provide a feeling of accomplishment and a temporary release of tension.

In order to allow the user to concentrate on the next relevant bridge, the next bridge only appears when the previous one has been successfully completed. This is intended to give the user less ambitious goals and thus, prevent overwhelming demands and resignation.

3.1.3. Tower Scenario

For the *Tower Scenario*, the patient's main task is to ascend a tower to the top. To provide more opportunity for height exposure, the tower is scaled by walking along slopes at its outside wall. Since the *Tower Scenario* is specifically intended to be the most difficult scenario, a tower design with outside ramps was realized (see Figure 2). Since climbing a tower steadily increases height, it is a good fit for graded exposure. At the beginning the ramps are still very wide and have railings. In the further course the railings disappear and the ramps become narrower. A platform in the middle of the tower can be used to provide rewards and give the patient a break from exposure. The second half of the tower consists of a transparent material, which makes it more difficult to direct the attention away from the environment by staring at a wall or the floor, and narrow ramps without railings should reflect the highest degree of difficulty.

3.2. Customization of the VE

In order to customize the experience based on the need of an individual patient, we implemented a couple of parameters, which the therapist can adjust. To increase the degree of immersion and the possible feeling of anxiety, virtual wind is generated depending on the height of the platforms, which moves the trees and is conveyed in the form of sound. An application parameter "wind strength" is intended to influence the perceived difficulty of the environment in terms of anxiety. The therapist is able to adjust the height of the platforms and wind strength separately or to automatically adjust the wind strength depending on the height of the platform. This can increase the plausibility of the environment and thus the level of presence. In addition, the therapist has the possibility to decide whether water should be at the bottom of the environment or not. Water can create a feeling of insecurity, as the depth of the water cannot be estimated.

Before the actual session, the therapist can test the environment and adjust the parameters via a menu accordingly. This enables the therapist to better assess the effects of the parameters on the environment and the patient's later experience. We assume that this will be the case especially at the beginning of the use of the VR application. Later, with more experience in the use and effects of the parameters, we assume that the remote control panel will be used more often.

(a) *Anxiety reporting* **(b)** *Treasure chest with badge* **(c)** *Pinboard with collected badges* **(d)** *Closing game*

Figure 4: *(a) Anxiety reporting function to indicate the current anxiety level. (b) chest with a badge inside used as a motivational element and (c) a pinboard as a progression measure. (d) Closing game at the end of the Tower Scenario.*

3.3. Locomotion

Navigation and locomotion pose a non-trivial challenge when the size of the VE exceeds the size of the real tracking area in which the user can move. There exist multiple interaction schemes for large-distance traversal in VR [AZMF18]. The most natural variant for this is the direct translation of real locomotion in physical space into virtual space. However, this requires a lot of free physical space, especially in large virtual worlds. Due to its speed and because it reduces motion sickness, *teleportation* is often used for VEs. Disorientation resulting from the instantaneous movement can be avoided by shortly fading the display while relocating the user. The disadvantage of teleportation can quickly put the user in an uncomfortable situation as there is no gradual approach to critical areas. In order to keep the space requirements low and at the same time allow for gradual exposure, we decided to use the joystick of the controller, which is very common in video games. So the user is able to use the joystick for locomotion, looking around and controlling the direction by turning his own body.

3.4. Anxiety Reporting

Anxiety levels during normal ET are typically reported by stating a number on a predefined scale. In our application, the patient can rate their perceived fear on a scale from 1 to 9 by using the joystick of the left controller (see Figure 4a). This allows the anxiety values to be recorded automatically and can then be analysed afterwards. Figures 2 and 3 show the positions where anxiety level reporting is requested.

3.5. Motivational Elements

Between phases of exposure, there should be opportunities to relax and calm down to release tension. These can additionally be used to motivate and reward the patient. Motivation and relaxation should take place in a relatively safe space, but still in the same environment as exposure to provide the opportunity for positive associations with the therapy environment. Engaging and interesting aspects of VR, such as interactions that can be considered enjoyable may be used. In the following, the implemented ideas for collectible badges as rewards and a closing game for a positive ending of a therapy session are discussed.

3.5.1. Collectible Badges

To improve motivation, collectible objects were designed as rewards and extrinsic motivators in-between exposure: Badges that can be earned by progressing through the scenarios. They serve as collectibles and constant reminders of the therapy progress they represent. For the prototype, each scenario will contain two badges to collect (see Figure 4b and 4c). A silver badge can be earned halfway through the scenario as part of a short break and a gold badge at the end of the scenario is awarded for successful completion of this segment. The user reaches a closed chest, which she first has to open and place the badge on a pinboard to earn the badge. Introducing the badges is an opportunity to introduce interaction into the virtual world, which can be intrinsically motivating. Requiring a certain effort to collect the reward can help to increase the perceived value. It is intended to add both extrinsic and intrinsic motivation elements that helps to extend interest in the therapy application.

3.5.2. Closing Game

Kahnemann and Tversky [KT79] coined the term *Peak-End Rule* for a rule of thumb about what instances of an experience have the most influence on how it is remembered. The rule states that how we remember an experience is disproportionately influenced by two factors: the most extreme experience (either most painful or most pleasant) and its last moments. This becomes important when we decide whether to engage in a past activity again. When "rating" a past experience, we have to rely on memory, which is influenced by how past experiences were encoded and consequently by the *Peak-End Rule*. Thus, the *Peak-End Rule* is essential in user-experience design [Has10]. In consequence of this rule, the end of the therapy session is an appropriate time to introduce motivational elements to increase the likelihood that it is remembered positively. At this point, the exposure tasks of the session can be assumed to be completed. Therefore, the application can focus on creating positive emotion and engagement. For this purpose, a small game was realized, which consists of a stack of boxes on a floating immovable platform. There is a small gap between the user's platform and the platform that is holding the stack of boxes. This gap is intended as an additional exposure element. The rules of the game are simple: the user grabs the stick and moves towards a marking that must not be crossed in order to gain points for shoving the objects (see Figure 4d). When the platform is empty, the game is completed and the final score is presented in order to add a competitive element.

4. Conclusion & Future Work

We implemented a prototype of a therapy application for VR treatment of acrophobia using a number of gamification strategies. Our tool gives the therapist the possibility to adjust the difficulty of the environment with the use of several parameters. In a planned study we want to evaluate our environment with acrophobia patients regarding the potential of our VE to induce anxiety. It is important that the scenario is considered realistic and plausible. For this purpose, the sense of presence and current anxiety values should be recorded. In addition, motion sickness symptoms will be recorded, as these can reduce the sense of presence [WKBC19] and can therefore also influence the perceived anxiety. The selected motivational elements should first be evaluated with regard to the suitability and interest of the participants. The motivational effect would have to be evaluated over several sessions in order to be able to assess the potential for long term motivation and the effects on the therapy.

The locomotion techniques considered in our work, the inclusion of further locomotion approaches (e.g. walking-in-place [WKMW16] or redirected walking [RKW01]) could have a positive effect on the success of the therapy and prevent possible motion sickness symptoms. The availability of railings, walls and a floor is highly important. These can be used to de-escalate situations. However, offering virtual railings that are not actually graspable could lead to problems as well. Another promising approach would be to record physiological data and analyze it over the course of the session. Also an adaptation of the VE based on the current physiological data is interesting. Research on interactive environments adapted to physiological data already exists. For example, Nacke et al. [NKLM11] focused on video games. Alternatively to automation, the control of the VE, for example the reordering of the bridges in the Bridges scenario, may be directly given to the patient in order to encourage experimentation with the exposure elements.

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