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VR-Based Exposure Therapy for Acrophobia: Effects of Visual Realism and Interactivity

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Abstract

Acrophobia, the intense fear of heights, affects a significant portion of the global population. Traditional therapeutic approaches, such as Cognitive Behavioral Therapy (CBT), have been supplemented by emerging technological solutions like Virtual Reality (VR). This paper explores the role of VR-based visual imagery in treating acrophobia. We examine the use of immersive environments, integration of multi-sensory stimuli, and how images in VR are designed to elicit controlled exposure therapy outcomes. Additionally, the paper discusses the impact of realism, scaling, and interactivity of VR-generated images on patient treatment efficacy. VR-based acrophobia treatment, particularly when leveraging realistic images and immersive environments, represents a promising advancement in therapeutic techniques for phobia management.

Keywords

Acrophobia, Virtual Reality Exposure Therapy (VRET), Physiological Monitoring, Treatment System Design, VR Scenarios

Introduction

Acrophobia typically manifests in late adolescence to early adulthood, affecting individuals aged 15 to 35 (Krijn, 2004; Botella, 2010). Research indicates that specific phobias, including acrophobia, have an incidence rate of about 5% among university students. Current treatments for acrophobia include cognitive behavioral therapy (CBT), exposure therapy, virtual reality exposure therapy (VRET), medication, and mindfulness therapy (Coelho, 2009; Leong, 2025c). VRET has gained widespread recognition due to its interactivity, flexibility, controllability, confidentiality, safety, and repeatability. However, challenges remain, such as the relationship between VR realism and anxiety, evaluating treatment effectiveness, the possibility of self-adjusting VR environments without a therapist, and the integration of auditory and tactile stimuli.

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To address these issues, this study designs a VR system that adapts based on patients' physiological indicators. The system employs the Pico 4 Enterprise VR headset and biometric hardware to monitor real-time data. It also integrates an emergency stop function, ensuring patient safety during treatment. The system applies Unity for game development and uses a database for data storage and analysis, allowing for exploration of adaptive thresholds. This study focuses on foundational methodological research and comparative analysis to establish a basis for future experimental validation. VR simulates real or imagined environments through computer-generated 3D virtual environments. Users interact with the virtual environment via head-mounted displays (HMDs), controllers, and other devices, experiencing immersive sensations involving vision, hearing, and touch (Schuemie, 2001; Leong, 2024a; Pan 2024). The user's perspective and interaction effects are continuously updated based on head and hand movement tracking. In VRET, patients confront their fears gradually and safely through simulated fear-inducing scenarios, such as heights or enclosed spaces. The controlled environment reduces real-world risk, and the difficulty level can be adjusted according to the patient's responses. For instance, the Oxford VR program, published in The Lancet, demonstrated that VR effectively treated three-quarters of participants with acrophobia.

Literature Review

The early use of VR in therapeutic contexts began in the 1990s. Researchers explored VR as a tool for exposure therapy, taking advantage of its ability to create realistic and interactive environments. One of the pioneering studies (Rothbaum et al. 1995) demonstrated that VR could be used effectively to treat fear of flying, setting a precedent for its application in other phobias. VR environments can simulate various heights with high realism, allowing patients to experience and confront their fear in a safe and controlled setting. Studies (Emmelkamp, 2002; Krijn, 2004) highlighted the potential of VR-based exposure therapy in reducing symptoms of acrophobia by providing an immersive experience that can be gradually intensified. Improvements in graphics, haptic feedback, and interactive elements have contributed to more immersive and realistic experiences. This section reviews recent literature on VR-based acrophobia treatment, focusing on the effectiveness of VR images and environments (Leong, 2024b; 2025b; 2025a). Recent studies have affirmed the effectiveness of VR-based treatments for acrophobia. Emmelkamp et al. (2002) conducted a study comparing VR exposure therapy to in vivo exposure therapy, finding that VR therapy significantly reduced acrophobia symptoms. Studies by Wiederhold et al (2003) and Botella et al. (2010) have explored these technological enhancements, demonstrating that improved VR systems contribute to better therapeutic outcomes. Comparative studies and meta-analyses have reinforced the effectiveness of VR-based treatments. A meta-analysis by Carl et al. (2021) reviewed multiple studies on VR exposure therapy for various phobias, including acrophobia.

Methodology and Experimental Setup

This section outlines the methodological framework and experimental setup used to evaluate the effectiveness of Virtual Reality (VR)-based therapy for acrophobia treatment, focusing on the role of immersive images in virtual environments. A randomized controlled trial (RCT) was designed

to evaluate the effectiveness of VR-based therapy in treating acrophobia compared to traditional exposure therapy. Participants were randomly assigned to one of two groups, VR-based exposure therapy (VR group) and Traditional in vivo exposure therapy (control group). Both groups received six weekly sessions of exposure therapy, with their progress assessed at multiple points during the treatment.

Participants were recruited from a pool of individuals diagnosed with acrophobia, meeting the criteria as outlined by the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders). Recruitment occurred through flyers at psychology clinics, online forums, and university counseling centers. The inclusion criteria were age 18 to 50 years old, diagnosed with moderate to severe acrophobia (using the Acrophobia Questionnaire, AQ). No prior experience with VR therapy. No history of severe motion sickness or vestibular disorders. Participants who were undergoing any form of cognitive-behavioral therapy (CBT) or were on medication for anxiety were excluded from the study to avoid confounding factors. In Apicella's study, A sample of 20 healthy subjects took part in the experimental activity. Before treatment began, participants underwent a pre-treatment evaluation that included: Acrophobia Questionnaire (AQ), Behavioral Avoidance Test (BAT), Physiological Measurements. This baseline data was used to compare changes in fear levels throughout the treatment.

For the experimental group, a VR-based system was created using high-end VR hardware (such as Pico 4, the Oculus Quest or HTC Vive) and specialized therapeutic software designed for treating phobias. The VR environment was tailored to simulate height-related scenarios designed to trigger acrophobic responses. The setup included motion-tracking sensors to monitor head and body movements, ensuring a fully immersive experience. The software environment was developed using Unity 3D to create realistic 3D images and height-based scenarios. The virtual environments ranged from standing on rooftops, bridges, and balconies to walking on suspended glass walkways. The environments were gradually intensified to provide increasing levels of height exposure. High-resolution, photorealistic images were rendered in virtual environments to evoke realistic fear responses. Factors considered in the design included: Depth perception, Environmental details, Dynamic lighting.

In addition to visual stimuli, the VR system incorporated auditory cues. The realistic sound effects such as wind, distant traffic noise, and creaking platforms were introduced to enhance the sense of immersion. In some scenarios, participants experienced slight vibrations or tremors through the VR controllers to simulate instability or motion often associated with high places. Each participant in the experimental group underwent six VR therapy sessions over six weeks, with each session lasting approximately 45 minutes. In the first session, participants were introduced to the VR equipment and environment, allowing them to acclimate to virtual surroundings without height stimuli. In subsequent sessions, participants were gradually exposed to height-related stimuli in the virtual environments. The intensity and difficulty level of the height scenarios increased progressively as participants demonstrated tolerance and reduction in anxiety. During each session, therapists employed CBT-based techniques such as deep breathing and cognitive restructuring to help participants manage their anxiety while confronting height stimuli.

Throughout the VR therapy sessions, participants' physiological and psychological responses were monitored in real-time. The Heart Rate Variability (HRV) is measured using a wearable monitor to assess the participant's stress response during height exposure. Galvanic Skin Response (GSR) captured to measure the intensity of anxiety responses during the exposure tasks. Subjective Anxiety Ratings where participants provided self-reported anxiety ratings on a scale of 1 to 10 at the start, middle, and end of each session. The control group underwent traditional exposure

therapy in real-world height scenarios. Each participant attended six therapy sessions in which they were gradually exposed to height-related stimuli in real life (e.g., standing near tall windows, climbing stairs to high floors, etc.). Anxiety levels, heart rate, and subjective anxiety ratings were recorded during these sessions, similar to the VR group.

After the completion of the six therapy sessions, participants underwent the same set of assessments as conducted pre-treatment. Follow-up assessments were conducted at one-month and three-month intervals post-treatment to evaluate the long-term effectiveness of both VR and in vivo therapies. The data collected during pre-treatment, during therapy sessions, and post-treatment was analyzed using statistical software such as python. Repeat measures ANOVA was used to assess the impact of time (pre-treatment, post-treatment, follow-up) and therapy type (VR vs. traditional) on participants' acrophobia symptoms. Each study provides unique insights into how different virtual environments induce varying levels of acrophobia, with many using height-based scenarios such as elevators, rooftops, and cliffs to elicit fear responses (Hong et al., 2017; Krijn et al., 2004; Rothbaum et al., 1995). The effects measured typically involve reductions in acrophobia over time, confirmed by both psychological and physiological markers. We referenced the scenes from the studies mentioned in (Hong et al., 2017; Krijn et al., 2004; Rothbaum et al., 1995; Kristína et al., 2024; Apicella et al., 2024; Russo et al., 2024) and independently designed three types of scenarios for our virtual reality system. These include:

Glass Bridge: In this scenario, users walk across a transparent glass bridge suspended at a significant height (see Figure 1). The clear visibility of the drop below induces a heightened sense of fear, allowing patients to gradually confront their fear of heights.

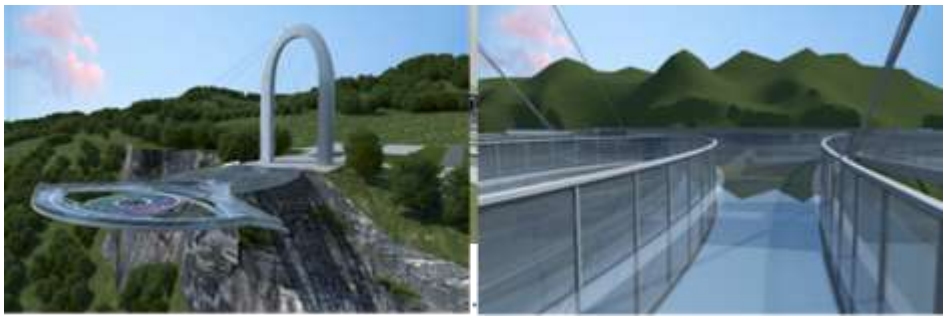

Figure 1. Glass Bridge

Airport: This environment simulates the experience of being at an airport, where users either sit in the cockpit or as a passenger, observing the surroundings from an elevated position (see Figure2). The goal is to expose patients to height-related anxiety while maintaining a sense of safety within the enclosed space of an airplane.

Figure 2. Airport

High-rise Building with a Glass Elevator: This scenario places the user in a skyscraper equipped with a glass-walled elevator. As the elevator ascends, users can look out over the city, progressively experiencing greater heights (see Figure 3). This scenario combines dynamic movement and a continuously changing view to gradually desensitize patients to height-related anxiety.

Figure 3. High Rise Building with a Glass Elevator

Results and Discussion

By comparing the patients' data across multiple scenarios, the analysis of exposure effects in the different environments is as follows.

The glass bridge scenario is designed to allow patients unrestricted movement, offering a controlled static visual stimulus. The primary focus of this scenario is to provide visual exposure to heights without introducing dynamic environmental changes, allowing for a gradual and manageable increase in anxiety levels related to the perception of height.

In the airport scenario, patients remain in a seated position, simulating the motion of an aircraft. This scenario combines a physically static experience with dynamic external stimuli, simulating the sensation of movement through changing visual cues. This setup introduces a moderate degree of anxiety as patients are exposed to height through perceived motion, while maintaining a passive physical state.

The High-rise Building with a Glass Elevator scenario introduces both physical movement and dynamic visual exposure. Patients experience a gradual ascent in an open-view elevator, simulating height changes in real-time. The increasing elevation and continuous environmental change provide a more complex stimulus, challenging patients with both motion and a progressively more intense visual perspective.

The intensity of sensory stimulation varies between these scenarios, with the level of patient exposure increasing as the virtual environments transition from static to dynamic. This allows for a controlled, scalable approach to treating acrophobia, ensuring that the level of exposure adapts as the patient's tolerance improves. The Acrophobia Questionnaire (AQ) was used to assess self-reported fear and avoidance of height-related situations. Both groups showed significant reductions in AQ scores from pre-treatment to post-treatment, but the VR group exhibited a greater decrease (Emmelkamp, 2002), shown as in Figure 4.

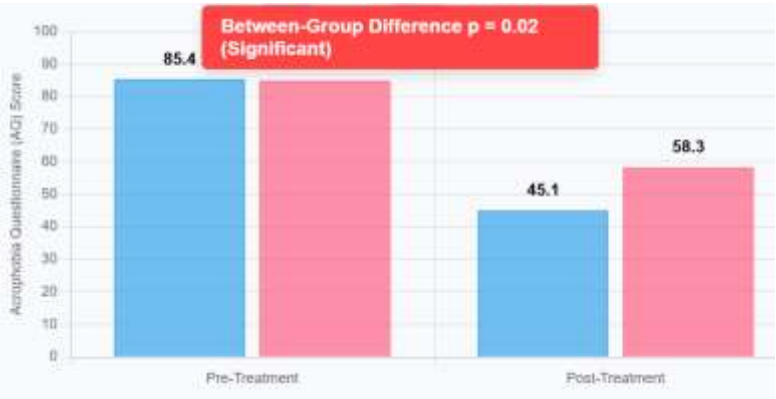

Figure 4. Comparison of VR vs In Vivo Therapy for Acrophobia

The between-group analysis using an independent samples t-test showed that the VR group had significantly lower post-treatment AQ scores compared to the vivo group ($\rho = 0.02$), indicating that VR-based therapy was more effective at reducing acrophobia symptoms.

Conclusion

This study demonstrates the adaptation of Virtual Reality (VR)-based exposure therapy, particularly using immersive, high-quality images, in treating acrophobia. The results indicate that VR-based therapy not only reduces self-reported anxiety and avoidance behaviors more effectively than traditional in vivo exposure therapy, but also leads to greater physiological desensitization, as evidenced by reductions in heart rate and galvanic skin response. Furthermore, participants in the VR group showed more sustained improvements in acrophobia symptoms during follow-up evaluations, suggesting that the immersive nature of VR environments fosters long-term benefits. The findings underscore the potential of VR technology to offer a controlled, customizable, and safe environment for phobia treatment. By allowing individuals to confront their fears in a virtual setting with a gradual increase in stimulus intensity, VR therapy provides a more effective and accessible alternative to traditional methods. The high realism of the images and multi-sensory integration in the VR environment likely play a critical role in these enhanced outcomes. In conclusion, VR-based acrophobia treatment, particularly when leveraging realistic images and immersive environments, represents a promising advancement in therapeutic techniques for phobia management. Future research should explore the application of similar VR technologies to other phobias and anxiety disorders to further validate its efficacy and broaden its use in clinical settings.

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