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Designing and Developing a Dual-Mode VR Game for Anxiety Intervention

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Abstract

Virtual Reality (VR) is increasingly recognized as a promising tool for mental health support. Recent studies suggest that immersive environments can reduce anxiety and improve emotional regulation by promoting presence and relaxation. The biofeedback generated from VR practices has shown positive results, suggesting that calming and immersive experiences can help reduce or prevent symptoms of anxiety and depression. This research aims to design and develop a VR game framework for anxiety intervention that aligns with mindfulness principles through calming, relaxing, and low-pressure interactions. In this game, players can choose a mode for structured plant cultivation tasks focused on active engagement or an open-ended environment exploration experience on passive observation, within immersive natural environments. Unlike clinical VR systems that require professional supervision and strictly controlled therapeutic settings, or commercial entertainment-oriented VR applications with intensive challenges that may increase player stress and cognitive load, our game emphasizes simplicity, mindfulness, and positive reinforcement. This work also establishes the foundation for the next stage of research, which will involve comprehensive user studies to evaluate both the short-term and long-term effectiveness of the system. Through the assistance of a DOED MSEIP awarded to UHD over three years, support for this project was realized through one of the competitive preferences, that of providing personalized and job-embedded professional learning experiences that advance student engagement. Further, mentored PhD research in advanced technologies within UHD laboratories ensures specialization topics and content are offered in a just-in-time manner. This grant award enabled the purchase of VR headsets, thus encouraging experimentation utilizing VR, as in this paper.

Keywords: Anxiety Intervention, Game Development, Mindfulness, Virtual Reality

1 Introduction

In today's increasingly fast-paced and overstimulated world, mental health issues are becoming more widespread. According to the data from the National Alliance on Mental Illness [1], approximately one in five adults in the United States experiences a mental illness each year, while anxiety is among the most prevalent mental health conditions [2, 3].

Anxiety disorders are often caused by complex biological, psychological, and environmental factors [4, 5, 6]. Patients often have difficulties with concentration and control, exhibiting rapid repetitive behaviors, persistent worrying and overthinking, and frequent switching from tasks [7, 8, 9], which can cause a wide range of personal and societal problems. Traditional psychological intervention methods for anxiety, such as Exposure Therapy [10, 11], provide controlled confrontation with stimuli that provoke anxiety to gradually build tolerance to anxiety and stress. However, these methods are often time-consuming and typically require professional supervision. In contrast, mindfulness-based intervention [12] focuses on progressively enhancing mindful awareness to improve emotional regulation and reduce anxiety symptoms, generally considered less intensive and stimulus-based. Mindfulness practices can be performed with minimal professional supervision through self-directed activities like structured exercises, breathing practices, audio-guided meditation, and digital platforms, and still demonstrate significant effectiveness in reducing stress and anxiety [13-16].

With advances in immersive technologies, Virtual Reality (VR) applications have increasingly been integrated into mindfulness practices [17-20]. VR systems are typically composed of head-mounted displays (HMDs), motion tracking sensors, and input devices such as handheld controllers. The headset, worn like goggles, displays a 3D virtual world, providing a realistic environment that users can navigate and interact with

via controllers. Beyond entertainment, VR is widely used in healthcare, education, training, and engineering applications [21, 22, 23]. The immersive experience from VR enables users to feel as if they are physically situated within a simulated environment, thereby enhancing their emotional responses to targeted interventions. The interactive nature of VR systems, supported by head-mounted displays and motion-tracked input devices, facilitates user engagement and feedback collection. Due to these features, VR has been broadly adopted in behavioral and physiological interventions, demonstrating the growing recognition of its therapeutic potential. Recent studies [24-27] indicate that VR-based applications can effectively alleviate symptoms associated with depression and anxiety. A typical example of these applications is the gamification of VR mindfulness systems, where serious game design principles are integrated into VR-based mindfulness interventions. In these systems, digital games often provide relaxing environments and use illustrative problem-solving techniques, which can help users cope with stress and negative emotions [28, 29]. Compared with traditional passive non-game mindfulness activities (e.g., meditation, breathing exercises, and body scans), gamification elements, such as real-time feedback, progression mechanics, adaptive environments, and goal-oriented tasks, can help to enhance user motivation and adherence to mindfulness practice [19, 21]. However, how to integrate these elements properly into VR systems to balance anxiety alleviation, system accessibility, and user engagement remains a challenge.

Many VR systems designed for mental health adhere strictly to clinical protocols and require structured supervision or controlled experimental settings, limiting their accessibility and usage. Conversely, commercial VR games are often performance-oriented and engage players through goals, challenges, and rewards, which may increase cognitive load and involve excessive self-evaluation, potentially conflicting with the non-striving and non-judgmental nature of mindfulness practices [30-34]. On the other hand, issues such as the lack of standardized design frameworks, limited transparency in development processes, and unclear methodologies [35, 36] make it difficult for researchers to identify and systematically study the factors influencing the development of VR games for mental health applications. These challenges highlight the need for more structured and transparent approaches to VR game design. A clear design rationale is needed to explain how gamification elements are integrated into the system to support core therapeutic principles, along with consistent methodologies and assessment concerns to enable the investigation of therapeutic outcomes across different platforms.

In this work, we present a dual-mode VR game developed to support mindfulness-based experiences and introduce our design considerations and development methods. The core design strategy is to replace performance-driven gamification mechanics with process-oriented, non-evaluative interactions that emphasize awareness rather than achievement, which aligns with the principles of mindfulness practices. Our work makes the following contributions. First, we provide a design rationale grounded in existing studies on mental health theories and game development, demonstrating how VR game design can be aligned with psychological principles. Based on the design rationale, we propose a structured framework for developing VR experiences for anxiety intervention, where a set of design principles from mindfulness and relaxation-based interventions is translated and interleaved into game mechanics. The proposed framework is implemented with a VR game prototype set in a natural environment, offering users two interaction modes: active engagement in structured activities such as plant cultivation (in the Bloom Space mode) and passive observation of calming scenes and environmental exploration (in the Star Gazer mode). The design of dual interaction modes enables the investigation of how users adapt to interventions through repetitive and gentle engagement, providing a foundation for further studies on how passive and active interactions may influence users' behavioral and physiological responses.

2 Related Work

According to the Mental Health Foundation [37], anxiety is a mental state triggered by various factors, such as threat, challenges, uncertainty, and environmental or psychological stressors. Anxiety can range from mild, everyday worry to more severe and long-lasting conditions that may require clinical support. Anxiety disorders primarily include the following categories [37]:

- Generalized anxiety disorder (GAD), often caused by stressful daily life situations;
- Panic disorder, invoked by sudden panic attacks;
- Phobias, which involve excessive fear of specific objects or situations;
- Post-traumatic stress disorder (PTSD), associated with a stressful or frightening experience;
- Social anxiety disorder, due to a fear of social situations.

With the rapid advances in VR technologies, many VR applications for anxiety treatment have been developed within clinical or research contexts. Anderson et al. [38] presented an early clinical application of VR-assisted exposure therapy (VRET) for treating public-speaking anxiety, a social anxiety disorder (SAD). Within the same cognitive behavioral therapy (CBT) framework, Robillard et al. [39] investigated the use of virtual human agents as therapeutic tools for treating SAD. In their system, users are exposed to controlled social situations, practicing social behaviors and gradually building confidence. VR exposure therapy is also used in the treatment of panic disorder and phobias [25, 40], where VR environments simulate the situational triggers eliciting patients' physiological sensations, to practice their coping strategies in a controlled setting. According to the review by Wu et al. [27], these VR-assisted cognitive behavioral therapy (VRCBT) systems need to align with structured exposure therapy protocols and require therapist-controlled settings and clinical monitoring during the process.

Instead of targeting specific anxiety disorders, commercial VR applications provide informal solutions to general stress management and everyday anxiety reduction, emphasizing relaxation and mindfulness-related experiences through immersive technologies. For example, TRIPP [41] combines guided meditation, breathing exercises, and virtual environments, providing users with a relaxing and calming experience. Similarly, the Flow [42] VR platform and Nature Treks VR [43] offer mindfulness practices through immersive nature scenes with soothing ambient sounds. However, most of these VR applications engage users with challenges for progression, reward feedback, and performance-driven mechanics, which may increase cognitive load and potentially trigger anxiety and stress.

In contrast to VRCBT systems that require clinical supervision and strictly controlled therapeutic settings, and commercial VR applications that pursue players' active engagement and performance-oriented interactions, our game emphasizes a mindfulness-oriented VR experience for general stress reduction and anxiety support. The system is not intended to treat specific clinically diagnosed anxiety disorders requiring formal

therapies, but focuses on providing supporting interventions that may potentially alleviate generalized anxiety associated with everyday stress and diffuse worries rather than specific intense triggers from fear or panic.

3 Methods

In this section, we present our approach to the design and development of the VR game, including the design rationale grounded in mindfulness intervention principles, the overall system framework, the game structure, and the game development environment and tools. We also introduce a dual-mode design, which provides players with both active and passive engagement experiences, and present screenshots of the game.

3.1 Game Design Rationale

As defined by Kobat-Zinn [44], mindfulness refers to a form of awareness that arises from intentional attention to experience at the present without retrospection or judgment of the past. Mindfulness-Based Stress Reduction (MBSR), developed by Kabat-Zinn, often uses practices like body scan exercises, mindful breathing, and guided mindfulness instruction to enhance present-moment awareness, improve emotional regulation, and reduce stress and anxiety symptoms [44, 45].

Our game is inspired by the intervention principles derived from MBSR, including non-judgmental, non-striving, attentional focus, and self-compassion [44-47]. Our design rationale based on these principles is detailed in Table 1.

Table 1. Our Game Design Rationale Based on Mindfulness Intervention Principles

Mindfulness Intervention Principles	Interpretation	Our Design Rationale
Non-judgmental	Observe instead of reacting with judgment	Avoid competitive scoring or performance ranking
Non-striving	Avoid forcing a particular outcome	Make the game experience process-driven instead of performance-driven; no failure outcome.
Attentional focus	Sustaining attention on the present moment	Use immersive environments and simple interactions to maintain user attention; encourage repetitive tasks without intense challenges.
Self-compassion	Encourage yourself with positive attitudes	Incorporate positive reinforcement, calming visual/audio feedback, and less cognitive load.

3.2 System Overview

Based on the above rationale, we developed the conceptual framework for the VR anxiety-intervention cycle (shown in Figure 1). This approach uses an iterative process in which the player's experience is progressively shaped, reinforced, and refined to support stress and anxiety alleviation. The process begins with a VR environment that provides a controlled and engaging setting for introducing therapeutic elements. Within this environment, calming visuals and ambient sounds are used to create a soothing atmosphere that promotes presence and relaxation. Rather than relying on explicit rewards, the system incorporates subtle visual responses to players' input, offering immediate yet non-intrusive feedback for progress and engagement. These responses contribute to positive reinforcement while maintaining a focus on the experience itself. As players begin to experience improvements in emotional well-being, they can continue engaging with the system and repeat the interactions. This iterative cycle facilitates ongoing exposure to therapeutic stimuli and supports the gradual development of coping skills.

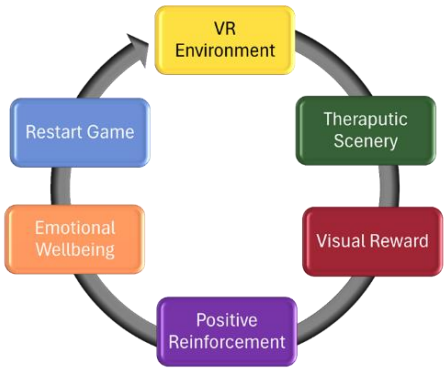

Fig.1. Framework for the VR Anxiety-Intervention Cycle

Fig. 2. The game offers two modes: Bloom Space and Star Gazer.

3.3 Game Structure

Many modern games often provide multiple interaction modes to accommodate different player preferences and play styles. In mindfulness-oriented applications, diversified modes allow users to choose activities that align with their psychological states and comfort levels and provide an adaptive and varied interactive experience [48, 31, 21]. In a VR game system, flexible modes can offer multiple forms of interaction, such as environment exploration, object manipulation, and passive observation, which help to sustain players' participation, enhance their immersion and engagement, and improve their anxiety reduction.

Our game offers two modes (shown in Figure 2): Bloom Space and Star Gazer. Bloom Space emphasizes direct and active interaction between the player and the environment, where players actively seek flowers and use the controller to water them. This mode aims at relieving stress and anxiety through attention training and gentle repetitive engagement with calming stimuli. Star Gazer provides more freedom and minimizes interface

distractions to players, allowing them to explore the environment freely and appreciate the beauty of the starry sky and peaceful surroundings. This mode focuses on passive exploration and reflective observation to support relaxation and emotional regulation. With the two modes, players can choose between active engagement and passive exploration depending on their emotional and cognitive needs, thus supporting personalized relaxation pathways for anxiety intervention.

3.3.1 The Bloom Space Mode

The design of the virtual world in the game is inspired by prior studies [49, 50, 51] that immersive, nature-based VR environments can foster relaxation and reduce anxiety, as virtual exposure to natural settings has been shown to enhance mood and alleviate stress. The virtual world of Bloom Space is designed as an open environment that includes natural elements such as blue sky, creek, trees, grass, mushrooms, and stones. We also included artificial objects such as bridges, pathways, and fences to provide a diverse spatial structure and guide players' navigation. The game immerses players in a space featuring visual elements such as a winding pathway crossing grass and a wooden bridge over a clear stream, and ambient audio such as distant bird songs, the gentle flow of a creek, and soft rustling wind in the background.

As structured repetitive activities have been widely discussed in psychology and mindfulness-related research for their potential support in anxiety reduction [13, 44, 47], in Bloom Space, we designed an activity asking the player to cultivate flowers. This activity requires a sequence of players' interactions with the system, including locating the flowers, watering the flowers, and observing the flowers grow and bloom. The core mechanics focus on interactive flower cultivation through user input, where players use handheld controllers to spray water droplets onto the soil mounds along the pathway and planter boxes distributed throughout the environment (as shown in Figure 3). When the droplets are released, a realistic water-pouring sound is triggered. The system detects interactions between water droplets and the soil, leading to the immediate growth of plants and flowers, thereby simulating real-world watering and growing processes (shown in Figure 4).

Fig. 3. Upper: planter boxes on the roadside; lower: soil mounds along the pathway.

Fig. 4. The process of planting and watering flowers.

Fig. 5. Upper: the gameplay screen; lower: the outcome for winning.

The design of Bloom Space supports attentional focus by helping users maintain awareness of ongoing sensory experiences. The repetitive activities in this mode are intended to foster sustained attention and gentle task engagement. To align with the mindfulness intervention principles, Bloom Space is specifically designed without failure states, timers, or levels,

avoiding punitive mechanics that may lead to frustration, stress, or self-criticism. Figure 5 shows the gameplay screen, which displays simple instructional text to minimize attentional distraction and cognitive load, as well as the outcome screen, which provides only positive feedback.

Fig. 6. The user interface when the game starts.

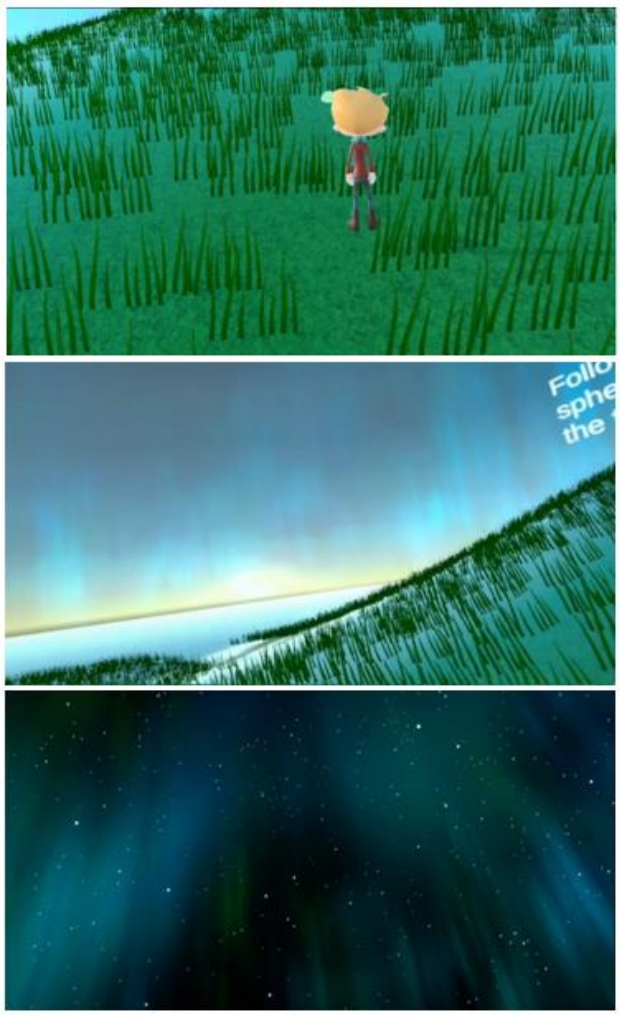

Fig. 7. Top: the player's avatar in the game; middle: viewing from the hill; bottom: viewing the starry sky.

3.3.2 The Star Gazer Mode

Compared with Bloom Space, the virtual world of Star Gazer contains fewer diverse natural objects, for the purpose of creating a wide, clean, and less distracting environment. By reducing environmental complexity, we emphasize spatial openness and visual simplicity of the scene, which allow players to move their attention away from task-oriented interaction to passive observation, particularly the starry sky and ambient natural sounds. This design supports mental relaxation by providing users with a low-demand and open-ended experience that enhances their sense of presence and calmness.

While Bloom Space engages players through repetitive watering activities, Star Gazer does not present players with any specific tasks or challenges, but instead minimizes the graphical user interface (GUI) (shown in Figure 6) and user input. The instructional text is displayed only when the player looks toward the top of the hill; when navigating in other directions, the screen contains no GUI elements that could disrupt the player's sense of immersion. In addition, there are no timers or completion conditions requiring the player to reach the destination; instead, the experience is intentionally open-ended. During the journey, players can look around and observe distant lakes, the horizon, and the starry sky (shown in Figure 7), while hearing ambient sounds such as the rhythmic chirping of insects and footsteps on the grassland. We expect to use this simplified interaction design to promote a slow-paced experience and a sustained sense of relaxation.

3.4 Game Development Environment and Tools

The game was developed using Unity [52] and implemented for virtual reality on the Meta Quest Pro headset [53]. We selected Unity as our game engine because it provides versatile cross-platform support and a well-established VR development ecosystem with convenient built-in tools for rendering, animation, and interaction design. To accelerate prototyping, we used publicly available assets from the Unity Asset Store [54-57] for environmental modeling and visual effects, and free ambient audio resources from Pixabay [58, 59]. These assets were used solely to support prototype development and were not part of the research contribution.

Meta Quest Pro is a standalone VR headset developed by Meta. It does not require a gaming PC or external sensors, allowing users to access virtual and mixed-reality environments simply by wearing the headset. It is equipped with built-in tracking cameras and handheld controllers, enabling users to move, look around, and interact with objects within a virtual space. Compared with earlier Meta headset models such as the Meta Quest 2, it offers enhanced support for immersive applications, including VR games and virtual practices. In addition, we are interested in its built-in eye-tracking functions, which can capture users' gaze behavior in real time, including fixation patterns and visual attention distribution. We expect to make use of this function to further analyze the player's attention and engagement during gameplay, thus helping us better understand user interaction patterns and improve the game design for enhanced immersion and mindfulness-based practices. Figure 8 shows the programming environment in Unity and the developer testing the game using the Meta Quest Pro headset and hand-held controllers. The final game product can be played independently without requiring a computer.

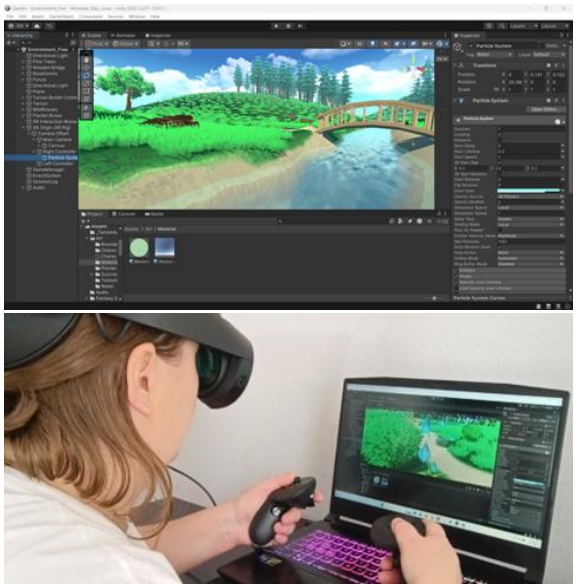

Fig. 8. Upper: the game programming environment in Unity; lower: the developer testing Bloom Space using Meta Quest Pro.

4 Conclusion and Future Work

This paper focuses on using technology and software development as a health resource. Imaginative products are needed to address difficult health situations. In particular, the area of mental health is not normally targeted through technology-related solutions. Mental health is surrounded by a range of cautious efforts to bring about actual solutions. This is the case due to stigmas associated with some solutions and many unsuccessful outcomes. In this work, we presented the design and development of a dual-mode VR game framework aimed at supporting anxiety intervention through calming, low-pressure, and mindfulness-oriented interactions. The proposed system integrates two interaction modes, Bloom Space and Star Gazer, which together balance active engagement and passive exploration within immersive natural environments. By providing the two complementary experiences, the system is expected to accommodate different user needs and psychological states, allowing players to flexibly transition between active engagement and relaxed awareness. The overall design emphasizes simplicity of interactions, reduced cognitive load, and positive reinforcement, aligning with mindfulness intervention principles.

While this paper outlines a clear need for further study on effectiveness and efficacy, this paper also offers a beginning toward emphasis on calmness, framed stressless scenarios approaching the affective domain of the user. Mindfulness is stressed in any mental health resource. Mindfulness may be the key to additional efforts of the gaming community to interject itself into the mental mindscape for future increased health. Since this system is not intended to provide formal therapy for specific anxiety disorders, but rather to offer supportive interventions for alleviating everyday stress associated with generalized anxiety, this paper focuses primarily on the system design and conceptual development of the game framework, rather than on evaluating clinical effectiveness. At this stage, our goal is to formalize design principles, set up the system framework, and demonstrate their feasibility through a prototype system. We expect this work to serve as a foundation for controlled user studies in the next stage, where we plan to evaluate the short-term and long-term effectiveness of the system and investigate how gamification elements and interaction modes affect diverse user groups.

Author Contributions

MJP, the project director, conceptualized the study and contributed to reviewing and editing the manuscript; LX, the faculty mentor, designed the methodology, mentored the student researcher, and wrote the manuscript; SM, the student researcher, designed the game modes and documented the game development procedure.

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Conflict of Interest: none declared.

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