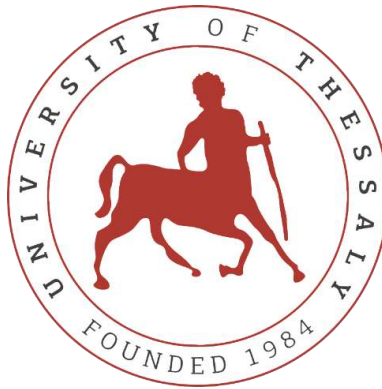




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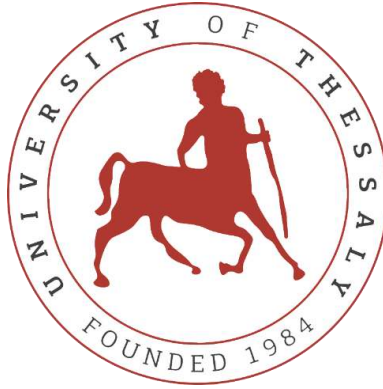
**DESIGN AND DEVELOPMENT OF A DIGITAL
APPLICATION FOR DEALING WITH
PHOBIAS**

Diploma Thesis

Panagiotis Argyropoulos

Supervisor: Hariklia Tsalapatas

February 2024



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ΣΧΟΛΗ ΤΜΗΜΑ ΗΛΕΚΤΡΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ
ΚΑΙ ΜΗΧΑΝΙΚΩΝ ΥΠΟΛΟΓΙΣΤΩΝ

**ΣΧΕΔΙΑΣΜΟΣ ΚΑΙ ΑΝΑΠΤΥΞΗ ΨΗΦΙΑΚΗΣ
ΕΦΑΡΜΟΓΗΣ ΓΙΑ ΤΗΝ ΚΑΤΑΠΟΛΕΜΙΣΗ
ΦΟΒΙΩΝ**

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Acknowledgements

With the completion of my diploma thesis, i would like to express my sincere gratitude to my friends and everyone else, who contributed in their own way and helped me reach at this point. First and foremost, i would like to thank my thesis supervisor, Ms. Hariklia Tsalapatas, who gave me the chance to work on this project and for all his valuable help and guidance during the development of this thesis. I would also like to thank my other supervisors, Ms. Eleni Tousidou and Mr. Athanasios Fevgas, for their participation and support. Last but by no means least, i would like to thank my beloved family for their unceasing and unparalleled love and patience, as well as for the continued moral and financial support throughout my studies. None of this could have happened without them.

Abstract

Acrophobia is a well-known and common fear—fear of heights and edges—among the human population. This dissertation aims to develop and implement a first-person application as a Serious Game (SR) and assess its therapeutic impact on users' fear of heights. The prototype enables exposure therapy to be conducted in a controlled environment, offering a more comfortable and cost-effective approach. The player is exposed to multiple levels with progressively varying heights in a realistic 3D environment. In each level, there are helpful quotes to assist the player in controlling their fear. By allowing full control over the player avatar and repeating the process, players can eventually overcome their fear either fully or partially. We can then evaluate whether a virtual reality environment is a viable alternative to real-life exposure.

Keywords: Acrophobia, Serious Game, Exposure Therapy, Virtual Reality

Περίληψη

Η ακροφοβία είναι ένας πολύ γνωστός και κοινός φόβος - φόβος για τα ύψη ή τα άκρα - μεταξύ του ανθρώπινου πληθυσμού. Η παρούσα διπλωματική εργασία στοχεύει να αναπτύξει και να εφαρμόσει μια εφαρμογή πρώτου προσώπου (Serious Game) και να αξιολογήσει τη θεραπευτική της επίδραση στους χρήστες όσο αναφορά την ακροφοβία τους. Το πρωτότυπο επιτρέπει τη θεραπεία έκθεσης (exposure therapy) να διεξάγεται σε ελεγχόμενο περιβάλλον, προσφέροντας μια πιο άνετη και οικονομικά αποδοτική προσέγγιση. Ο παίκτης εκτίθεται σε πολλαπλά επίπεδα με προοδευτικά μεταβαλλόμενα ύψη σε ένα ρεαλιστικό περιβάλλον 3D. Σε κάθε επίπεδο, υπάρχουν χρήσιμες συμβουλές για να βοηθήσουν τον παίκτη να ελέγξει τον φόβο του και επιτρέποντας τον πλήρη έλεγχο του μοντέλου (avatar) και επαναλαμβάνοντας τη διαδικασία, οι παίκτες μπορούν τελικά να ξεπεράσουν είτε πλήρως είτε εν μέρει τον φόβο τους. Με αυτό τον τρόπο μπορούμε να αξιολογήσουμε εάν ένα περιβάλλον εικονικής πραγματικότητας είναι μια βιώσιμη εναλλακτική λύση για την έκθεση στην πραγματική ζωή.

Λέξεις-κλειδιά: Ακροφοβία, Παιχνίδι Σοβαρού Στόχου, Θεραπεία Έκθεσης, Εικονική Πραγματικότητα

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1. Introduction

Acrophobia is a persistent and intense fear of heights, categorized as an anxiety disorder in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) [1]. Individuals with acrophobia may experience sudden panic, anxiety, and eyesight distortion in situations involving heights. This fear can be triggered in high places, while climbing a ladder, during airplane flights, and when looking over or close to edges.

The impact of acrophobia on a person's everyday life can be profound, with social implications such as limitations in activities, avoidance behavior, perceived judgment. This fear also has professional implications such as influencing job choices, workplace avoidance, and the decline of opportunities. Moreover, it extends to various aspects including physical health implications like stress, anxiety, limited physical activity, panic attacks, and isolation. In recent years, approaches to curing acrophobia have advanced significantly, with Serious Games applied in a therapeutic context emerging as one of the prominent technological solutions. While existing treatments for acrophobia, including exposure therapy efficacy, issues such as limited accessibility, time restrictions, patient engagement and lack of scalability persists. This study aims to address these challenges by developing a Unity-based serious game that focuses on the unique characteristics of acrophobia, offering a more effective treatment option. It particularly emphasizes providing an experience as close to real-life implementation as possible, aiming to overcome the limitations of traditional exposure therapy, and explores user experience and engagement. Game mechanics, such as setting goals, feedback mechanisms, and personalized progression paths, will be integrated to enhance user motivation and adherence. These objectives, aim to contribute insights into serious games as a treatment for acrophobia.

This dissertation is organized into several key chapters that provide a review of the existing literature on serious games for mental health, with a specific focus on acrophobia. It further details the methodology employed in the design and development of the serious game, followed by a comprehensive discussion, culminating in conclusions and suggestions for further development.

Unity engine is selected as the development platform due to its versatility and widespread adoption in the game development industry. Unity's cross-platform capabilities not only ensure accessibility to a broad audience but also extend to virtual reality (VR) headsets, thus maximizing the transferability of the serious game experience. This adaptability to VR aligns seamlessly with the specific requirements of creating an engaging and effective serious game for acrophobia, promising an immersive and accessible therapeutic intervention.

2. Literature review

When we typically think of the term 'game,' our minds often conjure images of video games, board games or card games, primarily developed for entertainment and amusement purposes. In contrast, the term 'Serious Game' refers to a game designed for specific educational, training, or informational purposes. The key aspect of these serious games is their engaging and interactive gameplay, aimed at teaching new skills, conveying messages, or addressing real-life problems.

2.1 Serious Games in acquisition of a new skill

A serious game, particularly in the context of learning a new skill, is a digital application designed with the specific purpose of facilitating skill acquisition, practice, and mastery. These games combine elements of entertainment with structured learning objectives to engage users and enhance their skill development process.

Splitting the context of learning in categories it begins with the ***Simulation*** that immerse users in realistic or hypothetical scenarios relevant to the skill being taught. These simulations often mirror the complexities of real-world situations, allowing users to apply their knowledge and skills in a risk-free environment. For example, a serious game designed to teach negotiation skills might simulate a business deal negotiation, complete with negotiation tactics, stakeholder interactions, and varying outcomes based on the user's decisions.

Interactivity lies at the center of serious games, enabling users to actively participate in the learning process. Users engage with the game through various actions, such as problem-solving, decision-making, and task completion. By providing opportunities for hands-on learning, serious games encourage exploration, experimentation, and deep understanding of the subject matter.

Immediate and constructive ***Feedback*** is crucial in serious games to guide users' learning progress. Feedback mechanisms inform users of their performance, highlighting areas of strength and areas needing improvement. Whether through in-game prompts, scores, or detailed performance reports, feedback helps users understand their learning trajectory, adjust their strategies, and strive for continuous improvement.

Adaptive (*Adaptability*) serious games leverage technology to personalize the learning experience for each user. These games dynamically adjust content, difficulty levels, and pacing based on individual learning styles, preferences, and performance metrics. By tailoring the learning experience to the user's specific needs, adaptive serious games maximize engagement, optimize learning outcomes, and accommodate diverse learners effectively.

Motivation plays a pivotal role in serious games, driving users to actively participate and persist in their learning journey. Gamification elements, such as rewards, achievements, leaderboards, and progression systems, tap into intrinsic and extrinsic motivators to incentivize desired behaviors and accomplishments. By fostering a sense of achievement, progress, and mastery, motivational features sustain user engagement and commitment to skill development goals.

Social features (*Social Interaction*) in serious games facilitate collaboration, competition, and communication among users. Through multiplayer modes, chat functions, forums, or social media integration, users can interact with peers, mentors, or instructors, enhancing the learning experience through social learning dynamics. Collaborative problem-solving, peer feedback, and community support contribute to a rich and engaging learning ecosystem within serious games.

Lastly serious games incorporate tools for monitoring and evaluating user performance over time. These *Performance Tracking* mechanisms enable users to assess their progress, set meaningful goals, and identify areas for further development. By providing visibility into learning metrics, achievements, and milestones, performance tracking empowers users to take ownership of their learning process, track their proficiency growth, and make informed decisions to enhance their skills effectively.

2.2 Serious Games as educational application

The integration of serious games into educational electronic applications represents a compelling strategy to revolutionize modern learning paradigms. Serious games, blending educational content with engaging gameplay elements, offer a transformative approach to education by captivating learners' attention and fostering active participation. These games, embedded within electronic applications, immerse users in interactive narratives, challenges,

and simulations, providing experiential learning experiences that go beyond traditional instruction methods.

By leveraging the motivational power of gaming, educational electronic applications can enhance engagement and motivation among users. Through captivating storylines, progression systems, and rewards, serious games inspire learners to invest themselves fully in the educational process, driving intrinsic motivation and sustained engagement. Moreover, the interactive nature of serious games facilitates experiential learning, enabling users to explore concepts, practice skills, and experiment with different strategies in a safe, simulated environment. This hands-on approach promotes deeper understanding, critical thinking, and problem-solving skills, empowering learners to apply their knowledge effectively in real-world contexts.

Furthermore, educational electronic applications that integrate serious games accommodate diverse learning styles and preferences, offering interactive, visual, and kinesthetic learning experiences. These applications foster collaboration and social learning through multiplayer modes and cooperative gameplay, promoting teamwork, communication, and interpersonal skills among users. Additionally, serious games serve as powerful formative assessment tools, enabling educators to gather real-time data on users' performance and progress. By analyzing gameplay metrics and interactions, educators can identify learning gaps, misconceptions, and areas for intervention, providing timely feedback and personalized support to learners.

Beyond academic achievement, the integration of serious games into educational electronic applications cultivates a lifelong love of learning and curiosity. By sparking curiosity, encouraging exploration, and inspiring self-directed inquiry, these applications instill a passion for continuous learning and personal growth. Moreover, serious games simulate real-world challenges and complexities, equipping users with practical skills and decision-making abilities to navigate the complexities of the modern world.

2.3 Serious Games in Health

Serious game development also involves health-related and rehabilitation purposes using interdisciplinary skills and various frameworks to ensure effectiveness and motivation [2]. One of the areas that has prominently applied this method is the field of mental health, offering assistance in managing mental disorders [3]. By utilizing technological tools like first-person perspective applications and VR, this approach leads to increased susceptibility and severity perceptions, ultimately resulting in greater persuasion [4].

First Person Perspective (FPP) and Virtual Reality (VR) are unique tools for researchers to delve into various conditions. It enables the creation of controlled, lifelike scenarios that can be tailored to simulate specific triggers or stressors relevant to different disorders. This level of environmental realism offers unprecedented insights into the psychological and emotional aspects of mental health, paving the way for a deeper understanding of the underlying mechanisms.

Virtual reality exposure therapy (VRET) has emerged as a promising and effective intervention for anxiety-related disorders, particularly phobias and post-traumatic stress disorder (PTSD). Despite its inherent limitations, studies have demonstrated encouraging results in the treatment of anxiety-related conditions. In the context of phobias, VR exposure therapy, including VR-based graded exposure therapy (VR-GET), has exhibited significant efficacy, with a notably larger effect size for PTSD symptoms compared to control groups. Specific instances, such as the treatment of spider phobia, showcase substantial success, with 83% of patients experiencing clinically significant improvement [5], [6], [7]. Additionally, the findings of using VR in acrophobia treatment are impressive, even with a low-budget virtual reality exposure, as demonstrated in this study [8]. The effectiveness of VR is comparable to exposure in vivo in reducing anxiety and avoidance in patients, with results maintained up to six months of follow-up.

Another related study stated that Self-guided VR acrophobia treatment is effective and leads to consistent reductions in self-reported anxiety both between levels and after treatment [9]. As evidenced by the outcomes of the treatments, the effects are immediate. By dynamically adjusting in-game parameters in real-time while the user is actively

engaging and exploring the virtual reality (VR) environment, an additional measure is introduced to further mitigate acrophobia symptoms, as expounded in this study [10].

2.4 Existing Serious Games for Acrophobia

In the practical application of this subject, a substantial number of serious games/games have been developed and are currently utilized by a significant portion of the population seeking assistance for acrophobia. These games are categorized into two groups: those designed to guide users gradually with low-impact changes to familiarize them with their fear of heights and those purely intended for entertainment. The latter, categorized as just games, employ varying degrees of psychological experiences—some more aggressive, others more friendly. Despite their entertainment focus, both categories exhibit merit in the context of exposure therapy.

Oxford VR, a spin-out company of Oxford University, has developed an automated virtual reality program that takes place in a large atrium that resembles a shopping center. Users are asked to perform a series of ever more challenging tasks to help them confront their fear, gradually ascending the building's ten floors. The program features a virtual therapist called Nic (Now I Can), who coaches people through various challenges like picking apples or rescuing a cat from a tree. Nic is equipped with voice recognition so that she can ask users if they feel comfortable going up a floor, or if they'd like to repeat a task. She can also gauge people's level of fear as they go along, by asking on a scale of nought to ten how afraid they feel [11].

Live Beyond Fear [12] is a VR serious game consisting of three levels. Initially, the user explores the ground level area. In the second level, the user is assigned tasks while still at ground level. The third and final level requires the participant to rescue a cat by walking across a bridge elevated from the ground. This design choice progressively exposes the user to various heights and situations.

ZeroPhobia [9] comprises six animated modules featuring explanatory voice-overs and a virtual therapist. It also includes mobile VR games set in a theater hall where users can climb ladders, repair platforms, and observe objects on the floor. Additionally, the program incorporates 360-degree videos, controlled by the user's gaze. Findings from an experiment involving 66 participants revealed that the optimal practice time in VR was approximately 25 minutes. The study concluded that prolonged exposure did not yield additional benefits,

and there was a significant reduction in self-reported anxiety between levels and after completing the treatment.

In this article by M. Abdullah and Z. Ahmed [13], two realistic scenarios—a mountain and a city view—are showcased. Interaction within these environments is facilitated through Kinect motion detection. The Head Mounted Display (HMD) kit utilized by VR Gear paired with a Samsung mobile phone. The 20 subjects were split into two groups: one group experienced real-world exposure over a two-month period, while the other underwent virtual exposure for an equivalent duration. The findings indicated a reduction in anxiety levels from 64% to 40% in the second group.

Regarding optimal interaction modalities in the field of VR exposure therapy, this research [14] revealed that the highest sense of presence was achieved when utilizing Motion Recognition Cameras, in comparison to Hand Controller systems. The study involved 20 participants engaging in a virtual environment centered on acrophobia. The participants were tasked with performing three consecutive actions: walking across a room and exiting onto a balcony, reaching the balcony railing and then catching an object at a specific distance away from the railing. Motion tracking shifted the responsibility of interaction from the user to the system, thereby enhancing immersion and presence.

As mentioned earlier, there are projects designed for entertainment purposes, and the level of exposure they provide is not suitable for therapeutic use. However, they hold value in the broader context of virtual exposure, as they can help identify phobias that users might not even realize they have. An example of such projects is 'Adventure Climb VR,' crafted by MXTreality [15]. This game is developed exclusively for Virtual Reality (VR) using the Unity engine. It places the user in the role of a virtual climber situated within a rocky landscape, endeavoring to ascend from steep edges and ultimately reach the summit. The game incorporates a falling mechanic, intensifying the experience and adding a layer of challenge to the climbing process. By offering users a virtual environment that simulates climbing scenarios, Adventure Climb VR contributes to the exploration and identification of potential acrophobia in individuals, underscoring the diverse applications of VR in the realm of exposure therapy and phobia detection.

Similar to Adventure Climb VR, a comparable scenario unfolds in 'The Climb,' a game developed by Crytek [16] using the Crytek Engine in VR. Once again, the user assumes the role of a virtual climber, yet this time the scenery is even more breathtaking. The game

features free climbing on a rocky mountain with a volcanic vista, urban climbing amidst skyscrapers with an urban panorama beneath the user's feet, and exceptional graphics that create a 3D environment vividly representing the real world. The scenarios and missions vary widely based on the stage and scenery selected by the user during the selection phase. These virtual environments not only provide entertainment but also serve as potential tools for exposure therapy, allowing users to confront simulated acrophobic scenarios in a controlled and immersive setting.

Another noteworthy example of this genre is 'Richie's Plank Experience' [17], developed by Toast for Virtual Reality (VR). In this immersive game, the player embarks on an elevator journey within a skyscraper, ascending to a considerable height. Upon reaching a high floor, the player is then prompted to walk forward onto a plank suspended from the building, exposing them to the vast open space with a city view, urban noises below, and the sound of a strong wind. The experience can be enhanced by physically walking on a real plank while immersed in this scenario, triggering both physiological and psychological responses. It is essential to note that while this game is not intended for therapeutic use, as it is designed for events and exhibits with a larger audience involvement, its immersive nature and ability to evoke realistic reactions demonstrate the versatility of virtual environments in creating impactful experiences.

"Only Up!" is a platformer game released in 2023 by SCKR Games but was later removed from Steam due to copyright controversy. In the game, players control Jackie, navigating through a junkyard by running, climbing, jumping, and using trampoline beds scattered around to advance through the obstacles. The goal is to reach the top of the map without the ability to save progress or encounter checkpoints. Additionally, players can slow down time to enhance control over Jackie's movements.

2.5 Data Collection and Biofeedback

More often these types of games are great source of extracting useful data for research purposes. A research study conducted in a virtual reality environment called Plank Challenge utilized a deep learning model to assess the acrophobia levels of individuals by analyzing the volunteer's EEG (Electroencephalography). This model demonstrated the capability to classify the volunteers' fear levels. In the study involving 66 subjects who participated in the virtual reality game 'Richie's Plank Experience,' users were exposed to

virtual heights while standing on a real plank. The deep learning model employed in the research achieved an average accuracy of 88% in detecting the volunteers' acrophobia levels.

Applying a similar approach, companies whose work involves heights and seeks to assess whether their employees have developed acrophobia can benefit from the VR simulator [18]. The virtual environment in these simulators comprises an aerial device with a moving platform and a virtual ladder positioned atop an electric pole, situated 11.6 meters above ground. The simulation includes various elements such as buildings, moving cars, rocks, and natural features like moving clouds. The use of HTC Vive trackers enables users to see their hands within the virtual environment, enhancing the overall immersive experience.

It is imperative to conduct observations in both the physiological and psychological domains. In this context, the term "**Biofeedback**" refers to a method of monitoring and providing real-time feedback on physiological and neurological processes that occur in response to stress. It is crucial to observe how the brain and the body response to stressful signals. This study by A. Landowska et al. [19] investigated the brain activity within the prefrontal cortex (PFC) of 13 individuals with acrophobia as they engaged in a virtual plank-walking scenario, six meters above the ground. Following the initial exposure to stimuli, a decline and subsequent increase in activity were observed in both the dorso-lateral prefrontal cortex (DLPFC) and medial prefrontal cortex (MPFC). This fluctuation normalized after the third exposure session, indicating successful reappraisal of fear-inducing stimuli post-therapy.

Furthermore, an elevation in oxygenated hemoglobin levels (HbO) was noted in the left DLPFC, supporting the notion that positive stimuli are predominantly processed in the left hemisphere, while negative stimuli are processed in the right hemisphere. Additionally, the left DLPFC exhibited activation during memory efforts directed towards recalling positive information [20], [21].

Individuals with phobias typically demonstrate decreased activation in the DLPFC and MPFC, coupled with heightened activity in the amygdala when confronted with fear-provoking stimuli. Both the DLPFC and MPFC play a crucial role in inhibiting amygdala activity and facilitating the reappraisal of negative emotions, demonstrating a negative relationship between their activity and that of the amygdala. In contrast, healthy individuals

exhibit increased DLPFC and MPFC activity when perceiving fear-inducing stimuli [22], [23], [24], [25], [26], [27], [28].

Paquette et al.'s study [29] highlighted significant right DLPFC activation in patients with spider phobia before cognitive-behavioral therapy (CBT) when exposed to phobogenic stimuli. Control subjects, when exposed to fearful stimuli, displayed left occipital gyrus activation, while phobic participants exhibited this activation post-CBT sessions. Johanson et al. observed right prefrontal cortex activation when subjects were exposed to a video featuring living spiders [30] .

Guo M. et al.'s [31] aimed to explore the local spontaneous neural activity and whole-brain functional connectivity patterns in the resting brain of acrophobia patients. For that cause 50 patients with acrophobia and 47 healthy controls were selected and all participants underwent resting-state MRI scans after enrollment. The results shown that patients with acrophobia exhibit local abnormalities in spontaneous neural activity and functional connectivity within specific brain regions, including the visual cortex, cerebellum, and orbitofrontal cortex.

This particular investigation by X. Cheng et al. [32] indicates that acrophobia has observable impacts on an individual's movement behaviors. In the virtual reality (VR) setting, a 60-story high building was crafted, and participants—both acrophobic and non-acrophobic—wore motion sensors on their wrists and ankles. These individuals were virtually transported to a high-altitude scenario through a simulated elevator experience. Within this virtual environment, a swaying wooden board extended outward, replicating the movement observed in the VR scene, leading to a high-altitude diving platform equipped with strategically placed basketball hoops and virtual tennis balls. Alongside with the virtual surroundings, a physical scene was set up, positioned 25 cm above the ground and precisely matching the virtual coordinates. Utilizing motion data collected from the participants wearing sensors, a robust classification model distinguishing between acrophobic and non-acrophobic individuals was developed. The results from this model confirmed the presence of discernible differences in the movement patterns of individuals with and without acrophobia in high-altitude environments.

In conclusion gathering valuable information during a person's exposure to a stressful event is crucial for advancing and optimizing existing technological applications in exposure therapy.

3. Methodology and software tools

3.1 User Story

As an individual struggling with acrophobia (fear of heights), I want a serious game app that provides a realistic virtual environment. This app should gradually expose me to varying heights and challenging scenarios in a controlled manner, allowing me to confront and manage my fear. I desire a personalized progression system that adapts to my comfort level, providing a supportive and engaging experience. The app should also incorporate relaxation techniques and guidance to help me build confidence and overcome my acrophobia gradually. By using this app, I aim to enhance my resilience to heights and regain control over my fear, ultimately leading to a positive impact on my daily life and activities.

3.2 Method

This study adopts a single-participant, self-reflective research design. As the developer and sole participant, the focus is on my personal experience as an individual with acrophobia, creating a Unity-based serious game with a first-person perspective and transferability to virtual reality. The objective is to offer an easily accessible and cost-effective application, while also gaining insights into the therapeutic potential of the serious game for acrophobia treatment.

Data collection involved self-observations and continuous feedback during the development process. As I engaged with the prototype standard first-person mode I recorded subjective experiences, emotional responses, and any observed impact on acrophobia symptoms. This iterative process allowed for the continuous refinement of the serious game based on my own reactions and perceived effectiveness.

The development process includes iterative cycles of creating, testing, and refining the serious game. Guided by my user story, each cycle involves creating and implementing features designed to simulate realistic scenarios triggering acrophobia. The iterative development approach is central to the user story's narrative, emphasizing the need for continuous improvement. Each development cycle is driven by insights gained from the previous phase, ensuring that the serious game remains responsive to the evolving needs of acrophobia treatment. The dual-mode functionality can strategically be integrated to provide

a comprehensive experience, allowing for a thorough assessment of the serious game's effectiveness in both standard and virtual reality settings.

- **Creation:** During the creation phase, scenarios are designed to induce controlled exposure to height-related stimuli, replicating realistic situations that trigger acrophobia. Unity's 3D environment capabilities are harnessed to build immersive landscapes and scenarios.
- **Testing:** Each scenario tested to evaluate its effectiveness in simulating acrophobia triggers. This testing phase involved both standard first-person mode and virtual reality mode, allowing for a nuanced understanding of the user experience in different contexts.
- **Refinement:** Feedback gathered through self-observation and reflections, guided the refinement phase. Adjustments to environmental factors, stimuli intensity, and game mechanics are made to enhance the therapeutic impact of the serious game.

The dual-mode functionality is a deliberate choice to facilitate a comprehensive examination of the serious game's impact. Standard first-person mode provides insights into the game's effectiveness on traditional platforms, while virtual reality mode offers an immersive and potentially more intense experience. The user story directs the inclusion of both modes to capture a holistic understanding of the serious game's influence on acrophobia symptoms across different modalities.

The user story acted as a guiding line throughout the development cycles. It directed the creation of scenarios that resonated with personal acrophobia triggers, ensuring authenticity in the serious game's content. The iterative approach aligns with the user story's emphasis on adaptability, allowing for a dynamic response to emerging insights and challenges encountered during the development process.

Ethical considerations involved maintaining the privacy and well-being of the sole participant (myself). The serious game's content is designed with sensitivity to acrophobia triggers, and the development process prioritizes emotional well-being and self-care. Regular self-check-ins and debriefing sessions are conducted to ensure a supportive and ethical environment.

Given that the study involves a single participant, generalizability to a broader population may be limited. The study's strength lies in its exploration of the developer's personal experience with acrophobia, providing insights that may inform further research in this area. The prototype phase is also acknowledged as a limitation, with future studies needed to validate the serious game's efficacy on a larger scale. Another limitation encountered during the development phase was the lack of VR equipment for conducting thorough tests, debugging, and general optimization. However, the VR mode has already been implemented in the prototype, with the usage and presentation designed to occur in the first-person perspective mode.

3.3 Software Tools

The serious game is developed using the Unity engine, facilitating integration of 3D models, virtual environments, and interactive elements. Although other engines, including Unreal Engine IV, were considered for development, prior experience with Unity proved more efficient, ensuring better results in a shorter timeframe.

In the development process using Unity, C-Sharp (C#) (programming language developed by Microsoft that runs on the .NET Framework) serves as the language for scripting and implementing the scripts to various elements to enable different functionalities. Its flexibility and compatibility with Unity's scripting API facilitate the development of interactive features that contribute to the serious game's therapeutic goals.

As it mentioned in the limitation section there is a VR integration but the lack of equipment made the testing difficult. Nevertheless, it can incorporate the Oculus SDK to enable virtual reality experiences and this allows for the transferability of the serious game between standard first-person mode and virtual reality, enhancing the overall user experience. The user story emphasized the importance of providing a seamless transition to VR for a more immersive therapeutic experience.

Blender, AutoCAD Architecture, alongside with Unity's assets store are employed for creating the virtual environment, the models and the animations in some aspects of the game. The model of the player/character/avatar that being used imported and finalized with Mixamo. The urban environment of the city site was created by importing assets from the Unity's asset store (cars, trees, rocks, roads etc.) and creating buildings, skyscrapers and

bridges in blender and AutoCAD Architecture software tools. These tools and models contribute to the visual appeal of the serious game, enhancing the realism of virtual environments and supporting the immersive nature of the experience.

The player model's movement control utilizes the embedded functionality provided by Unity, modified to align with the specific requirements and unique characteristics of the project. Scripts governing movement speed lock, camera locks, and teleportation for transitioning between stages have been incorporated.

Lastly the testing involved the use of Unity's built-in testing framework with regular playtesting sessions being conducted to identify and address any issues and ensuring the serious game's stability and functionality throughout the development cycle.

The table below provides more information about each tool:

Unity Engine	Unity is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Worldwide Developers Conference as a Mac OS X game engine. The engine has since been gradually extended to support a variety of desktop, mobile, console and virtual reality platforms. It is particularly popular for iOS and Android mobile game development, is considered easy to use for beginner developers, and is popular for indie game development. The engine can be used to create three-dimensional (3D) and two-dimensional (2D) games, as well as interactive simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering, construction, and the United States Armed Forces.
	C SHARP is a general-purpose high-level programming language supporting multiple paradigms. C# encompasses static typing, strong typing, lexically scoped, imperative, declarative, functional, generic, object-oriented (class-based), and component-oriented programming disciplines. The C# programming language was designed by Anders Hejlsberg from Microsoft in 2000 and was later

C#	approved as an international standard by Ecma (ECMA-334) in 2002 and ISO/IEC (ISO/IEC 23270 and 20619) in 2003. Microsoft introduced C# along with .NET Framework and Visual Studio, both of which were closed-source. At the time, Microsoft had no open-source products. Four years later, in 2004, a free and open-source project called Mono began, providing a cross-platform compiler and runtime environment for the C# programming language. A decade later, Microsoft released Visual Studio Code (code editor), Roslyn (compiler), and the unified .NET platform (software framework), all of which support C# and are free, open-source, and cross-platform. Mono also joined Microsoft but was not merged into .NET. As of November 2023, the most recent stable version of the language is C# 12.0, which was released in 2023 in .NET 8.0
Blender	Blender is the free and opensource 3D creation suite. It supports the entirety of the 3D pipeline—modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. Advanced users employ Blender’s API for Python scripting to customize the application and write specialized tools; often these are included in Blender’s future releases. Blender is well suited to individuals and small studios who benefit from its unified pipeline and responsive development process. Blender is cross-platform and runs equally well on Linux, Windows, and Macintosh computers. Its interface uses OpenGL to provide a consistent experience. To confirm specific compatibility, the list of supported platforms indicates those regularly tested by the development team
	AutoCAD Architecture (abbreviated as ACA) is a version of Autodesk's flagship product, AutoCAD, with tools and functions especially suited to architectural work. Architectural objects have a relationship to one another and interact with each other intelligently. For example, a window has a relationship to the wall that contains it. If you move or delete the wall, the window reacts accordingly.

AutoCAD Architecture	Objects can be represented in both 2D and 3D. In addition, intelligent architectural objects maintain dynamic links with construction documents and specifications, resulting in more accurate project deliverables. When someone deletes or modifies a door, for example, the door schedule can be automatically updated. Spaces and areas update automatically when certain elements are changed, calculations such as square footage are always up to date. AutoCAD Architecture uses the DWG file format but an object enabler is needed to access, display, and manipulate object data in applications different from AutoCAD Architecture
Unity Asset Store	Unity's Asset Store is an online marketplace where Unity developers can find, buy, and sell various assets, resources, tools, and plugins to enhance their game or application development projects. The Unity Asset Store provides a wide range of assets, including 3D models, textures, animations, audio clips, scripts, shaders, and complete project templates. These assets can be integrated into Unity projects, saving developers time and effort in creating everything from scratch.
Mixamo	Mixamo is a web-based service and platform that provides tools for creating and customizing 3D character animations. It was originally an independent company but was later acquired by Adobe. Mixamo offers a wide range of pre-built 3D character animations that users can apply to their own 3D models, saving time and effort in the animation creation process. The platform allows users to upload their 3D character models and then apply animations from Mixamo's extensive library. It supports a variety of file formats commonly used in 3D modeling, such as FBX and Collada (DAE). Mixamo also provides features for customizing and fine-tuning animations to suit specific needs,

	including adjusting the timing, blending different animations together, and more. Additionally, Mixamo offers an Auto-Rigging feature, which automates the process of adding a skeleton (rig) to a 3D character model, making it ready for animation.
IntelliJ IDEA	IntelliJ IDEA is an integrated development environment (IDE) written in Java for developing computer software written in Java, Kotlin, Groovy, and other JVM-based languages. It is developed by JetBrains (formerly known as IntelliJ) and is available as an Apache 2 Licensed community edition and in a proprietary commercial edition.
System Specs	CPU: AMD Ryzen 7 5800X3D 3.4GHz GPU: EVGA GeForce GTX 1080 8GB RAM: G.Skill TridentZ 16Gb 3200 MHz STORAGE: Samsung 970 M.2 NVME 250GB

Table 1: A consolidation of tools used for the development of the Serious Game

4. Implementation and Proof of Concept

To delve into the concept of this serious game, the scene begins with the player/user spawning in an urban environment on top of a building, constituting the initial segment of the first level. The path for further progression is discernible, creating a one-way route from the user's starting point. These levels are connected through bridges, specifically linking the rooftops. As the user approaches the edges of each building, it triggers a visual vertigo effect, varying with intensity in each level and progressively intensifying, reaching its peak in the last two levels. This visual distortion replicates what an acrophobia patient experiences during exposure.

To advance, the user must traverse the first bridge connecting the starting point with a taller building. The camera movement—restricted from left to right, up and down—combined with limited player movement speed during the bridge crossing ensures the evocation of an acrophobic sensation. At the end of the first bridge, the player reaches the conclusion of the 1st level, which consists of two buildings. It's noteworthy that each building features distinct terrains; some include railings on the edges, while others have a mix of railings and some with no railings at all. This varied structure creates a sense of safety for the user while serving the purpose of scalability for future runs.

Approximately 50 units (in-game metric) away from a designated point on that level, an interface becomes visible as an integral part of the 3D environment, presenting a helpful message. At the end of every level, a different message appears in a similar manner. The message interface rotates according to the player's position on that level to ensure visibility from every viewpoint.

The 2nd level comprises four buildings of different heights, following the same pattern. At the end of this level, another message appears. The 3rd level commences with a view of a house-like structure situated atop the current building, serving as the passage for the user to reach the conclusion of the 3rd level. This structure features two floors with glass walls to provide a 360-degree viewpoint. Via a bridge connecting to the structure, the user reaches the culmination of the 3rd level at the second and final building, which appears as a dead end. At this point, a popup interface message displays a helpful message. Simultaneously, another message prompts the user with a question, asking if they are ready for the next step. The background view of the message indicates the upward direction,

accompanied by a message instructing the user to press the R button to access the skyscraper. The user is then teleported into the first of two skyscrapers constituting the 4th level, visually positioned at a significantly higher altitude than before. This heightened elevation is indicated by the view, showcasing the user above some clouds. Near the edge of the skyscraper, the floor is made of glass, creating the illusion for the user that they are literally 'walking on air'. Descending through a glass bridge/passage, the user arrives at the second and final skyscraper of the 4th level, triggering the appearance of the 4th helping message. Notably, the vertigo effect on this level is more severe, activating sooner, particularly during the initial runs of the game before the user becomes accustomed to the heightened exposure.

Seemingly another dead end, an interface is displayed with a message instructing the user to press the T button for the final stage. Upon activation, the user teleports across their current location to a narrow rooftop of a tall building, indicating the commencement of the 5th stage. This building is the sole structure comprising the 5th stage, characterized by a narrow terrain that restricts the user's movement—a complete departure from the freedom of movement in the four preceding levels. From this vantage point, the user can observe their entire progression, from stage 1 to 4 and now to 5, providing a realization of the journey they have undertaken. The message to press ESC to exit displayed in conjunction with the last helpful message assists the user in concluding their experience. The total time required to complete the walkthrough is approximately 5 to 8 minutes or more, depending on the user's interaction style and the pace at which they choose to process the environment and engage with the feedback mechanics of the game.

An additional feature not previously mentioned is the incorporation of real-life traffic noises throughout the entire walkthrough. These authentic sounds have been recorded by the BBC. This element plays a crucial role in enhancing the overall experience, aiming to replicate the realism of a genuine real-life scenario.

4.1 Simulation of urban environment traffic in a Virtual Reality environment

Developing a comprehensive and realistic traffic simulation within a virtual reality (VR) environment is a multifaceted endeavor that demands thorough planning and precise execution. Such VR environments can be used for diverse purposes, including driver training, urban planning, gaming, and entertainment. Connecting to the topic of this thesis, traffic simulation has been important in order to provide a realistic sensation to the user and enhance his or her engagement in the environment.

Based on the scope of the VR application, selecting the suitable VR hardware and software platform is pivotal for project success. Several options exist nowadays, with different VR platforms like Oculus Rift, HTC Vive and others offering distinct capabilities and development tools. The platform choice significantly influences the development process and, consequently, the level of realism and immersion attainable.

At the core of any VR traffic simulation lies the 3D visualization environment. This encompasses creating the virtual world, which includes components such as road networks, vehicles, buildings, pedestrians, and other elements mirroring the real world. Tools like Blender, Unity, or Unreal Engine are commonly utilized for 3D modelling and environment design. Attention to detail is critical to create an environment that feels genuine and immersive. However, despite the virtualization environment tools, VR environment realism hinges on precise vehicle modelling and physics simulation [33], [34]. Vehicles in the VR environment must be represented as 3D models that respond realistically to user input and the environment. This encompasses aspects such as acceleration, braking, steering, and interactions with other vehicles. Implementing realistic physics in the vehicles ensures their movements closely resemble those in reality.

Authentic traffic behaviour in the virtual world necessitates the use of Artificial Intelligence (AI) algorithms that mimic real-life driving. This involves formulating rules for actions such as lane changes and overtaking maneuvers [35], adherence to traffic signals [36], yielding the right of way, and responding to unexpected situations. Efficient pathfinding algorithms are imperative for determining optimal routes and navigation within the virtual city, especially when one considers emerging modes of transport like Electric Vehicles [37], [38] and Autonomous Vehicles [39], [40]. An emerging research direction in

this field is using agent-based simulations, which are traditionally used for the strategic planning of real-world networks [41]. In the context of this thesis, several packages have been examined on the Unity platform. While they have all been examined for their realism and the opportunity to augment the VR environment created, it has been noticed that high-end packages are usually associated with relatively high prices for their licensing.

Thorough testing is vital to ensure the VR traffic simulation is both realistic and performs optimally. Rigorous testing helps identify and rectify any defects or performance issues. With emerging agent-based simulations being a prominent tool for efficient modelling and simulation in VR environments, the validation of the agent-based traffic behaviour [42] is also very central to the creation of a user-friendly VR environment. Sound effects contribute significantly to the immersion of the VR environment. Incorporating realistic audio elements like engine sounds, horns, and ambient noises enhances the overall experience. In the context of this thesis, we have used BBC's actual footage sounds from this webpage¹ to include sound effects in the VR environment and increase the resemblance to real-world settings.

In brief, creating an authentic traffic simulation in a virtual reality setting is a demanding yet fulfilling undertaking that calls for a multidisciplinary approach and cooperation among 3D artists, game developers, and potentially experts in traffic engineering and modelling. It is expected that in the next few years, Unity packages utilizing agent-based simulations can bring greater realism to VR environments.

¹ BBC's webpage, <https://sound-effects.bbcrewind.co.uk>

4.2 The 3D Environment

In this section, we will delve into the visualization of the concept and the features mentioned in the previous sections, beginning with the player model/avatar as shown in figure *Figure 1*. The decision to equip it with headphones is made with considerations for potential future features that are planned to be implemented, which we will discuss in the upcoming section of this thesis.



Figure 1 : The Player Model/Avatar

The developed environment consists of an urban scene featuring a small park at the center, including a small lake. Surrounding the park is a two-way road filled with cars, simulating traffic. Alongside the roads, there are buildings of varying heights and two skyscrapers are positioned in the vicinity. The pictures of the environment are taken from angles that the gameplay doesn't permit the player to proceed, and are captured solely for demonstration purposes. In *Figure 2* the first three levels of the gameplay are displayed, consisting of buildings characterized as medium height, with significant variation in height between them.



Figure 2: West scene view

Figure 3 and *Figure 6* depicts the two skyscrapers that comprise level 4, showcasing a significant height difference compared to the previous levels. Additionally, the dynamic sky adds to the realism of the experience. Level 4 is notably more challenging than the preceding levels, with the skyscrapers positioned above the cloud levels to heighten the intensity of the experience.

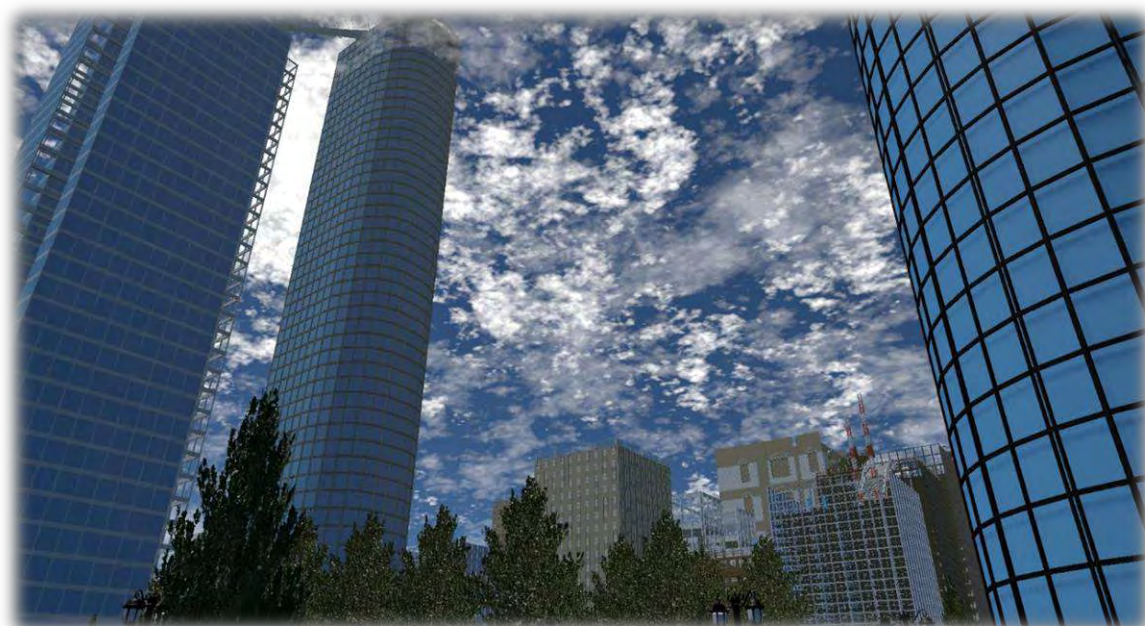


Figure 3 : Skyscraper view from below

The following figures (*Figure 4, Figure 5*) showcase the eastern (in-game) view of the scenery, featuring the museum alongside the park and the traffic roads, which serve as the focal point of the entire scene.

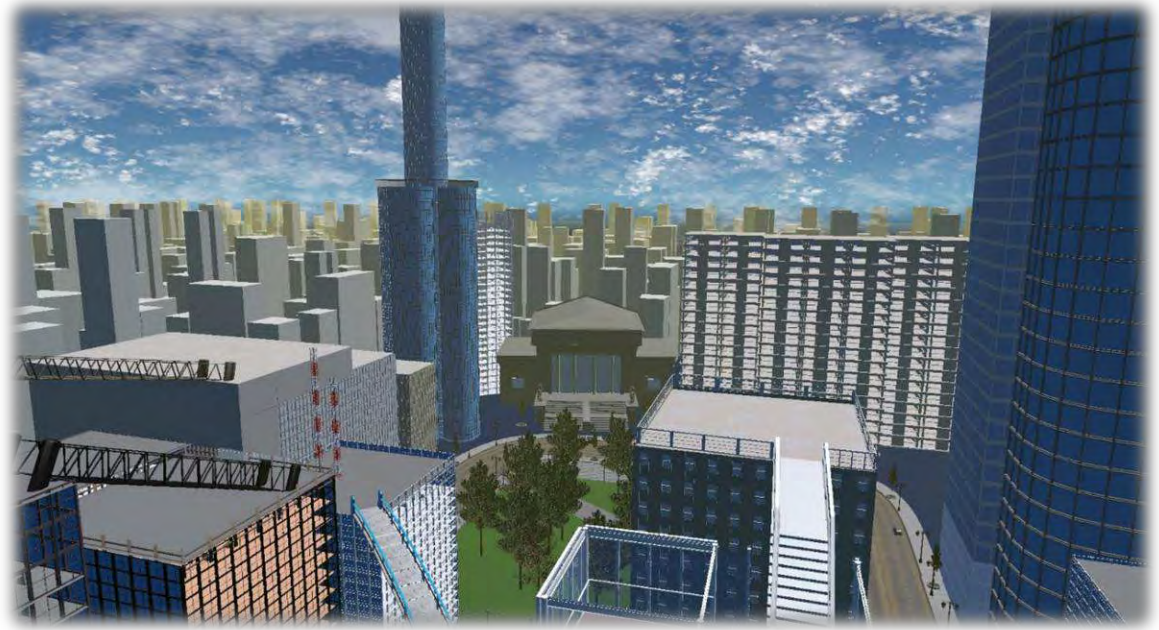


Figure 4 : Scene view from east

The street view is taken to demonstrate the perceived height experienced by the user in-game, highlighting that even the medium-height buildings present a significant challenge and provide an accurate representation of everyday structures.



Figure 5 : Street view

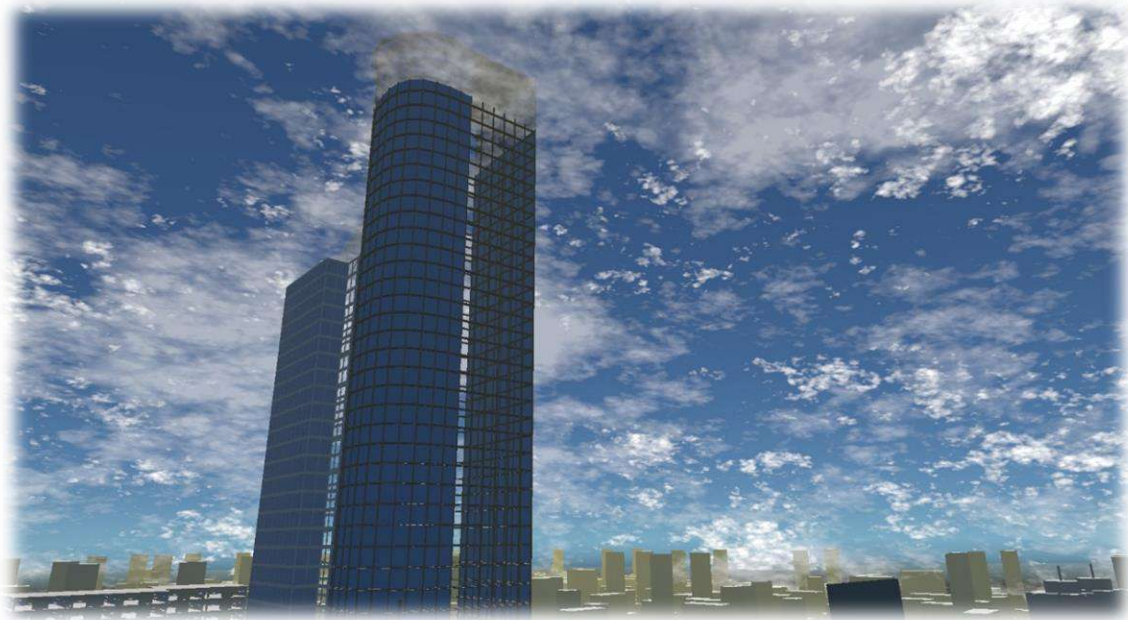


Figure 6: Skyscrapers view

The remaining space *Figure 7*, not directly involved in the game's purpose and player walkthrough, encompasses the main scene with civil building blocks and outlines of real-life embassy models, churches, museums, and more, reflecting various architectural elements.

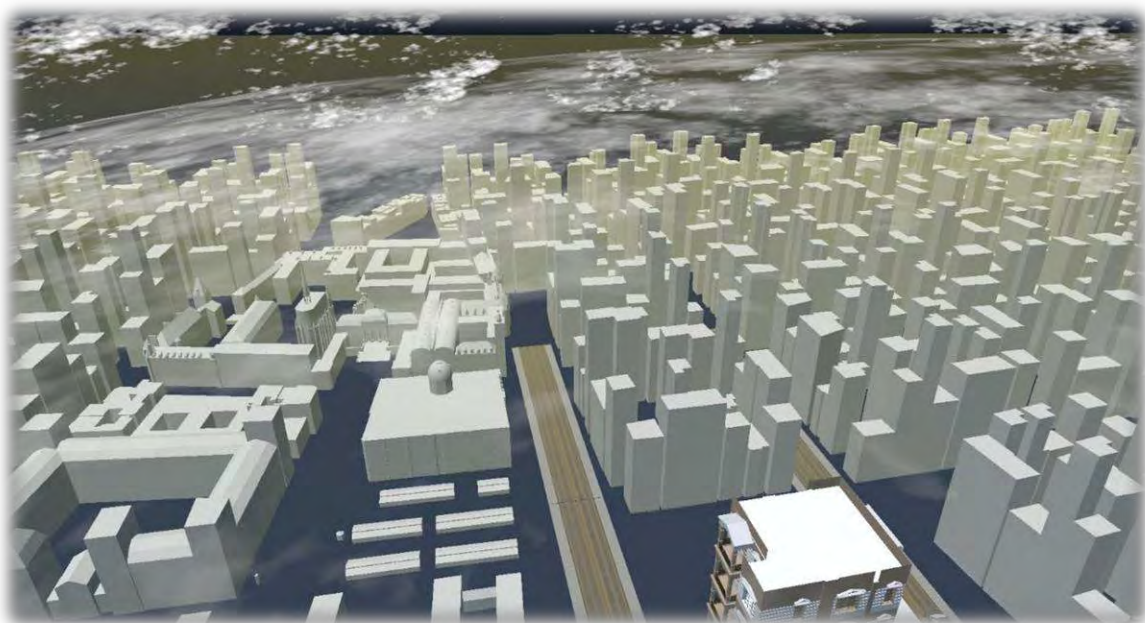


Figure 7: The world around the scenery

4.3 Walkthrough: Stages and features

The total number of stages/levels required to complete the walkthrough is 5. Stage 1 comprises 2 parts (2 buildings) as illustrated in section 4.3.1. Similarly, Stage 2 consists of 4 parts (4 buildings). The subsequent stages, 3, 4, and 5, follow the same scenario with varying numbers of buildings, heights, and terrain features. These features will be presented in the following subchapters. Each chapter will follow the path of the initial player field of view (FOV) upon arriving at the current level/stage, the display of a helping message (if applicable on the final building of the current stage), the variation in the vertigo effect view displayed (which differs from level to level), and at the point of passage/way (in dead-end buildings, it displays the teleportation message) for transitioning to the next building.

4.3.1 Level 1

The initial position/spawn of the character and the start of the game are depicted in *Figure 8*. At this point, the player can hear ambient traffic noises in the distance and the ambient wind noise, while also observing dynamic moving clouds. Upon entering the virtual environment, it triggers not only the sense of vision but also the sense of hearing.

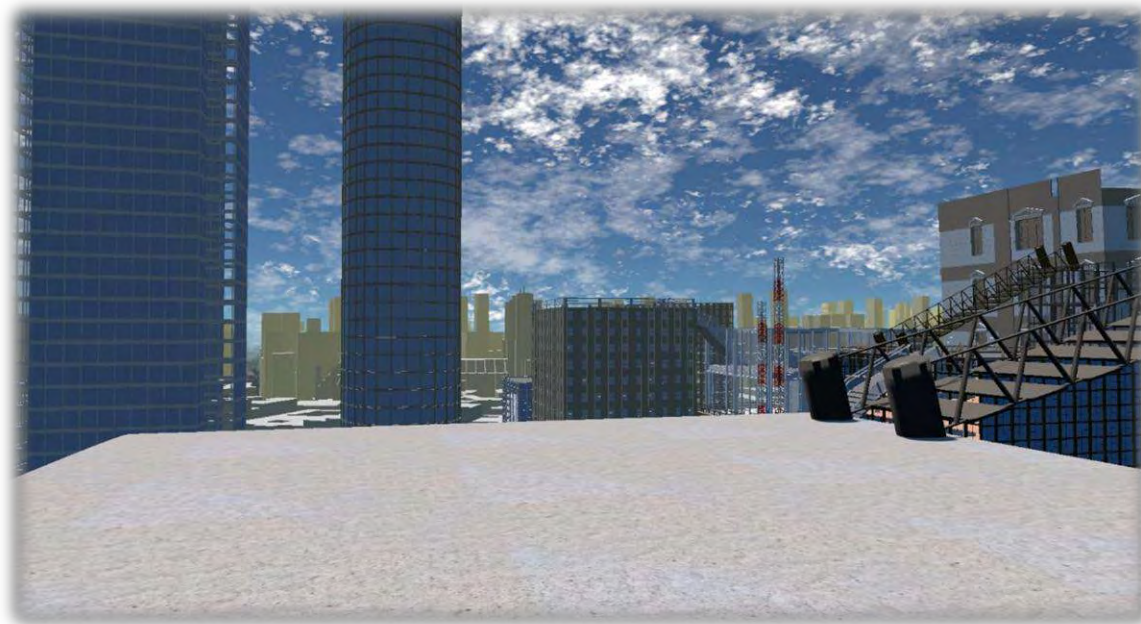


Figure 8: Player spawn, level 1, stage 1

As the player approaches close to the edges, the vertigo effect, implemented as the primary feedback mechanism, is triggered. This effect is represented by rapidly zooming in on an object in the center of the user's field of view, followed by an instantaneous un-zooming. The visual of that effect can be seen in the *Figure 9* and *Figure 10*.



Figure 9: Vertigo effect un-zoomed level 1 stage 1



Figure 10: Vertigo effect zoomed at level 1, stage 1

The picture below, *Figure 11*, illustrates the first bridge constructed, along with the other bridges connecting consecutive stages and levels. This specific bridge links stage 1 and stage 2 of the first level. An additional feedback mechanic not depicted in figures is the behavior that the player receives when crossing the bridges. The movement speed of the player model is reduced by half of the regular movement speed, and the camera is locked in a straight line within the field of view of the user.



Figure 11: Passage from stage 1 to stage 2, level 1

As depicted in the *Figure 12*, this marks the first view of the player upon entering the second half of the 1st stage. At the top left, the 1st helping message begins to fade in as the player approaches closely to the interface's position.

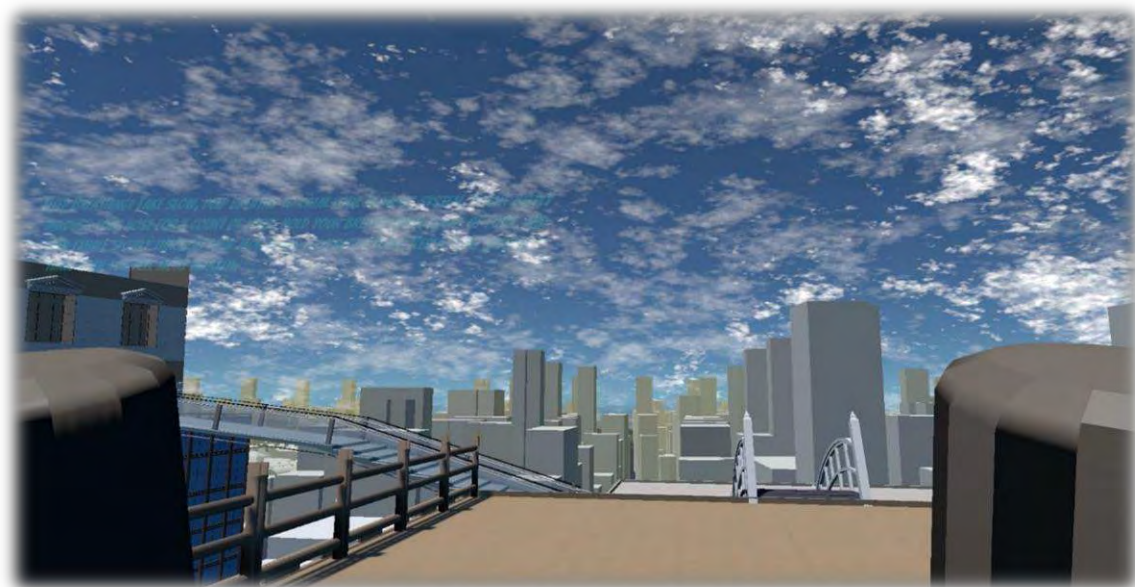


Figure 12: View at stage 2 of level 1

The helping messages in this stage suggest a breathing technique to assist the player in becoming more relaxed and lowering the levels of stress they may be experiencing. The justification for implementing a similar breathing suggestion, specifically diaphragmatic breathing, during VR exposure for aviophobia (fear of flights) users is supported by research indicating that individuals using this technique had a higher tendency to effectively overcome the fear of flying. Furthermore, it was found that such breathing techniques didn't interfere with the treatment outcome and, in some cases, even enhanced the treatment effects of VR exposure [43].

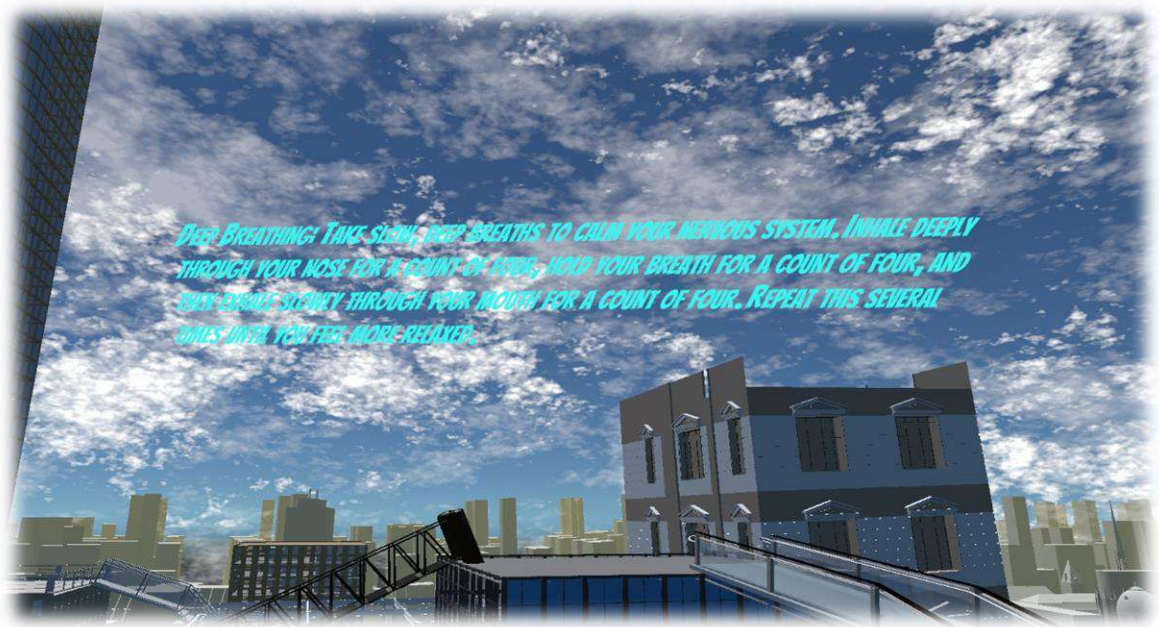


Figure 13: Helping message at level 1

The Vertigo effect from the 2nd stage of the 1st level is displayed in *Figure 14* and *Figure 15*. It is worth mentioning that the Vertigo effect, including the amount of dolly (the zoom and un-zoomed effect), is not instantly cancelled after leaving the triggering area. It takes some time for the user's initial field of view to return, and this duration depends on the height of the building and the current level the user is in.

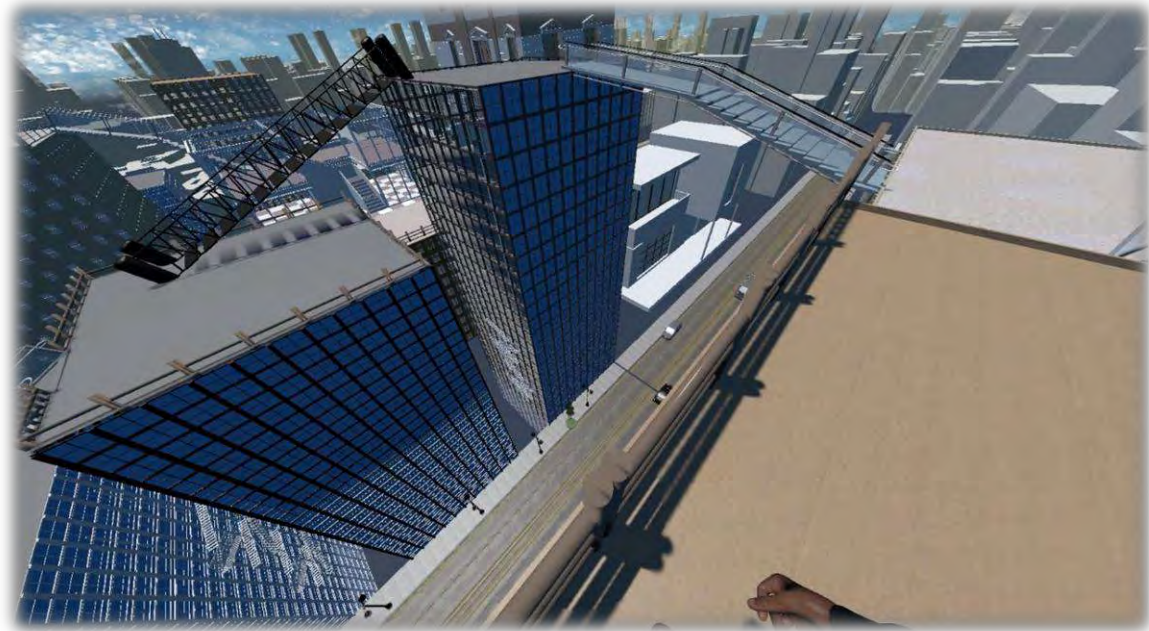


Figure 14: Vertigo effect un-zoomed at level 1, stage 2



Figure 15: Vertigo effect zoomed at level 1, stage 2

The pictures taken couple of frames apart and showing the extreme zoom and un-zoomed effect from the players perspective. The bridge connecting the last stage of the 1st level and the first stage of the 2nd level *Figure 16*.

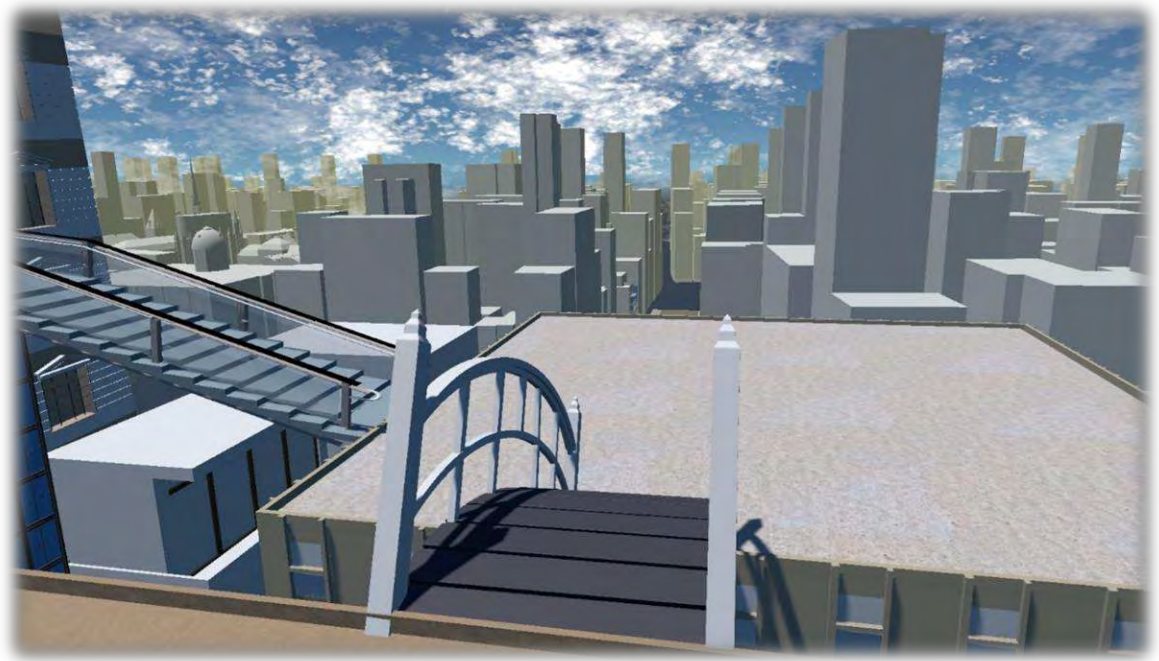


Figure 16: Passage to level 2

4.3.2 Level 2

The player's perspective at the 1st stage of the 2nd level reveals the continued presence of the helping message from the 1st level, now rotated towards the current position of the user. In *Figure 17* is displayed the bridge that connects this stage with the next one.

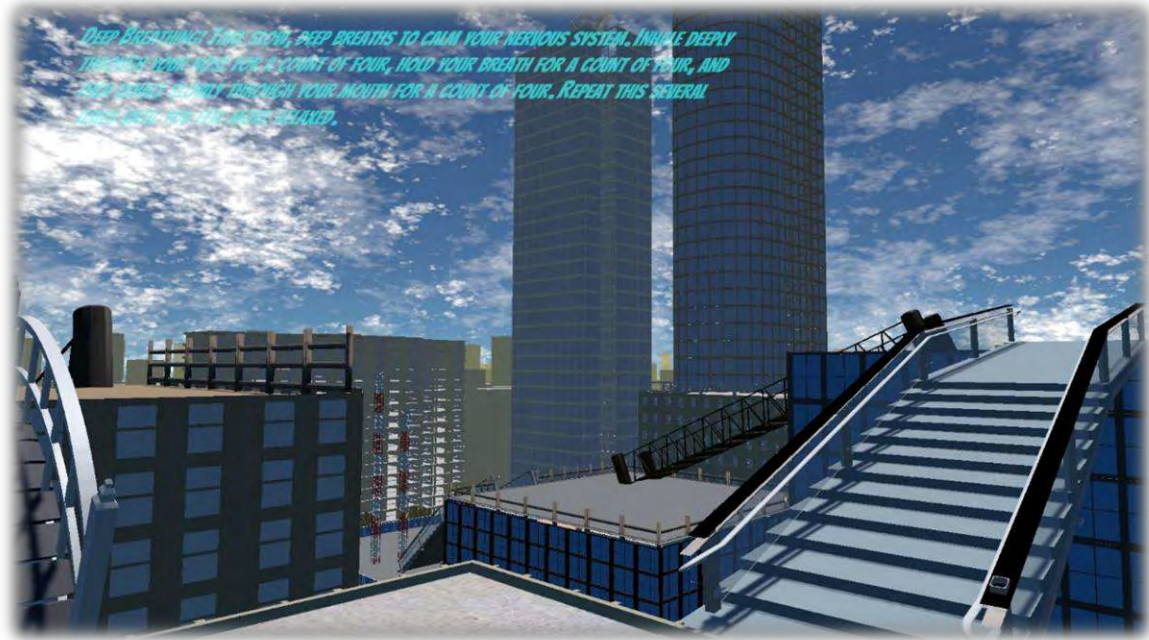


Figure 17: View from stage 1 and the passage to the next stage, level 2

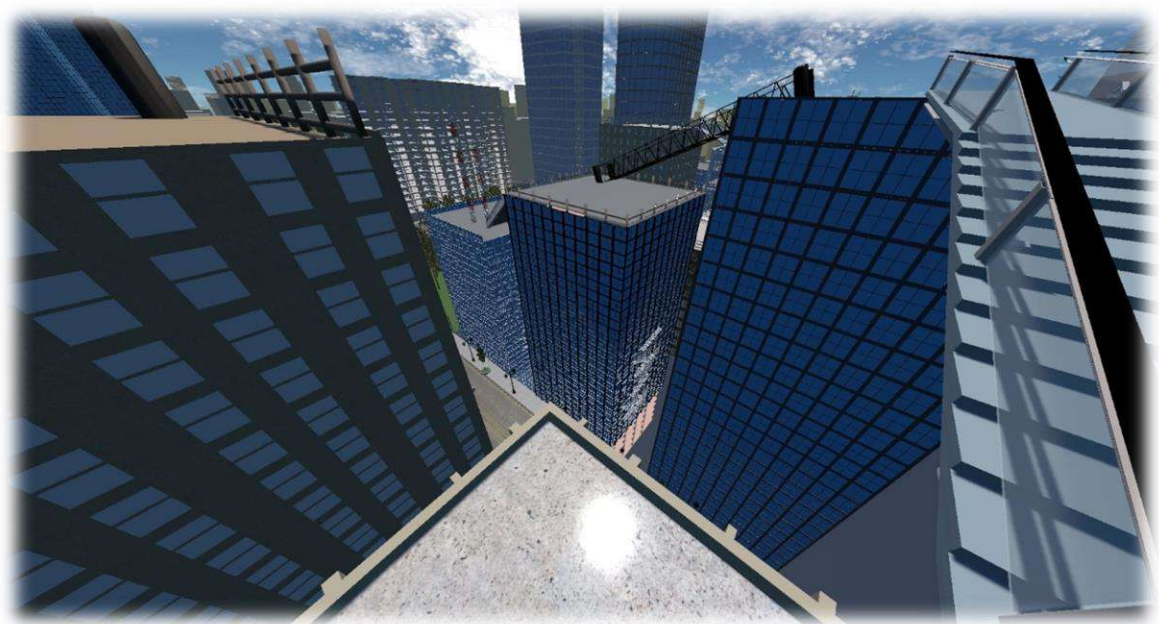


Figure 18 : Vertigo effect un-zoomed level 2, stage 1

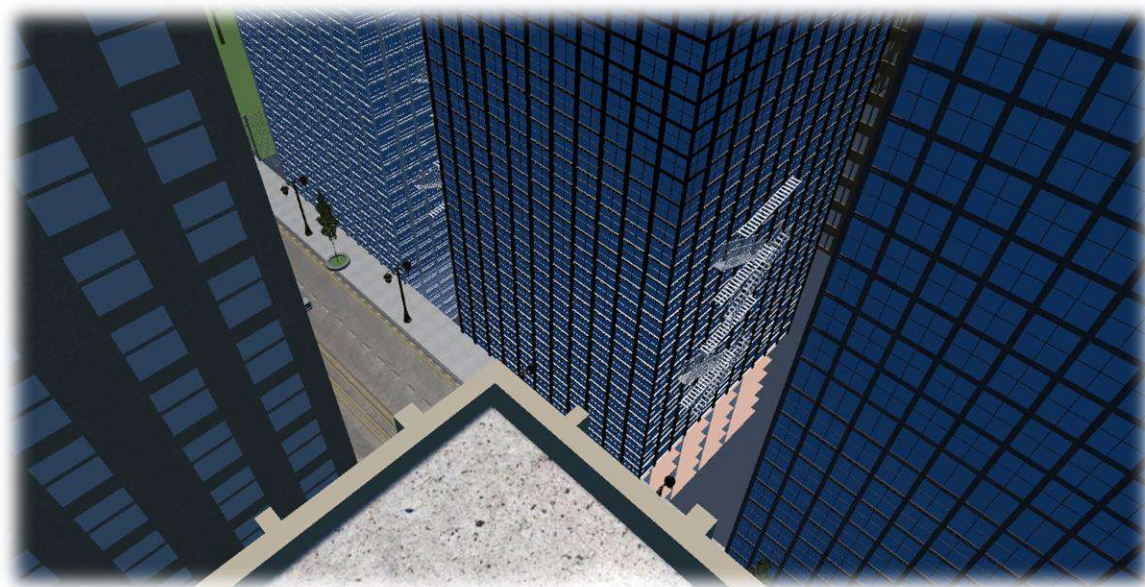


Figure 19: Vertigo effect zoomed, level 2, stage 1

The vertigo effect from this stage can be seen in the *Figure 18* and *Figure 19*. The effect, as can be seen, is more aggressive despite the building being shorter than the previous one. However, the absence of railings justifies the intensity of the effect.

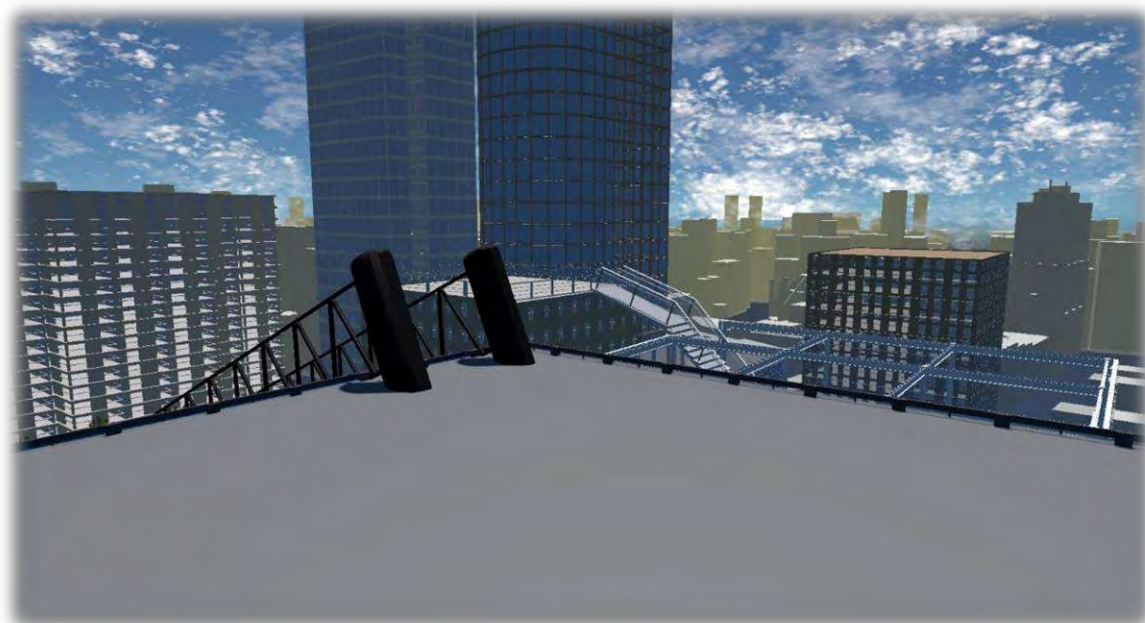


Figure 20: View from stage 2, level 2, stage 2

The initial view of the 2nd stage of the 2nd level is displayed in *Figure 20*. At this point, the user can clearly see the 3rd level as well as the 4th level, providing them with insight and visibility into what lies ahead and the effort required to proceed to further levels. The vertigo effect of that stage is displayed in the *Figure 21* and *Figure 22*. The scale of the effect follows the same pattern as the previous stage.



Figure 21: Vertigo effect un-zoomed level2, stage 2

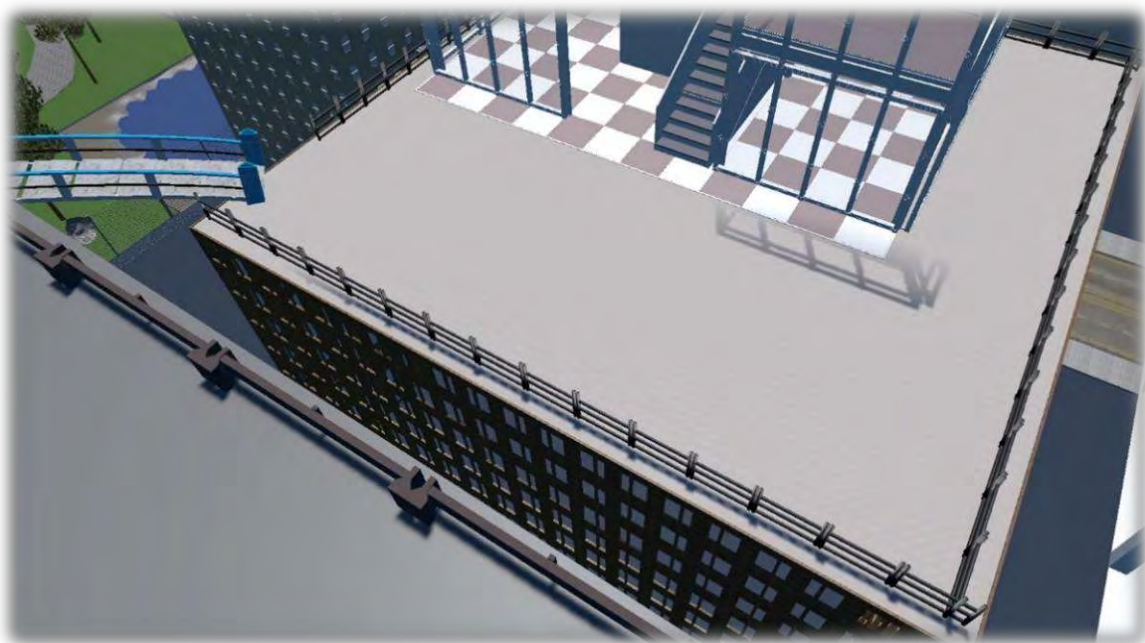


Figure 22: Vertigo effect zoomed level 2, stage 2

As the user descends towards the 3rd stage of the 2nd level via the bridge (*Figure 23*), they can now clearly see the end of the 3rd level, as well as the buildings they have already traversed during their current walkthrough. This allows them to compare their current state of stress/anxiety with previous levels. Such observation can assist in viewing the situation from a different perspective, aiding in the realization and identification of the source of fear.

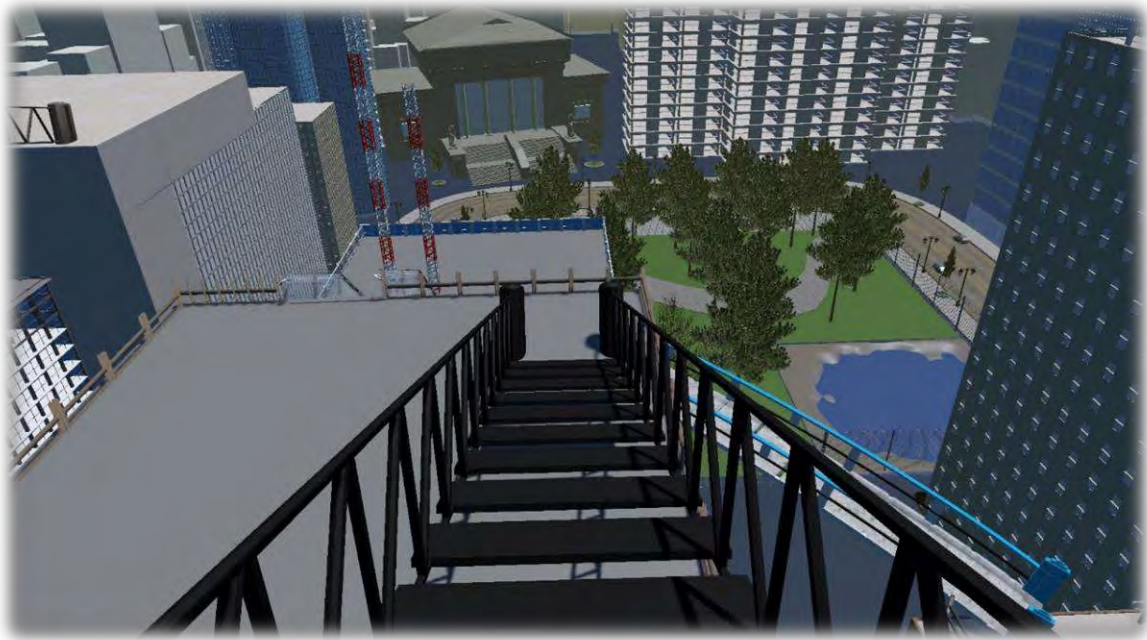


Figure 23: Passage to next stage

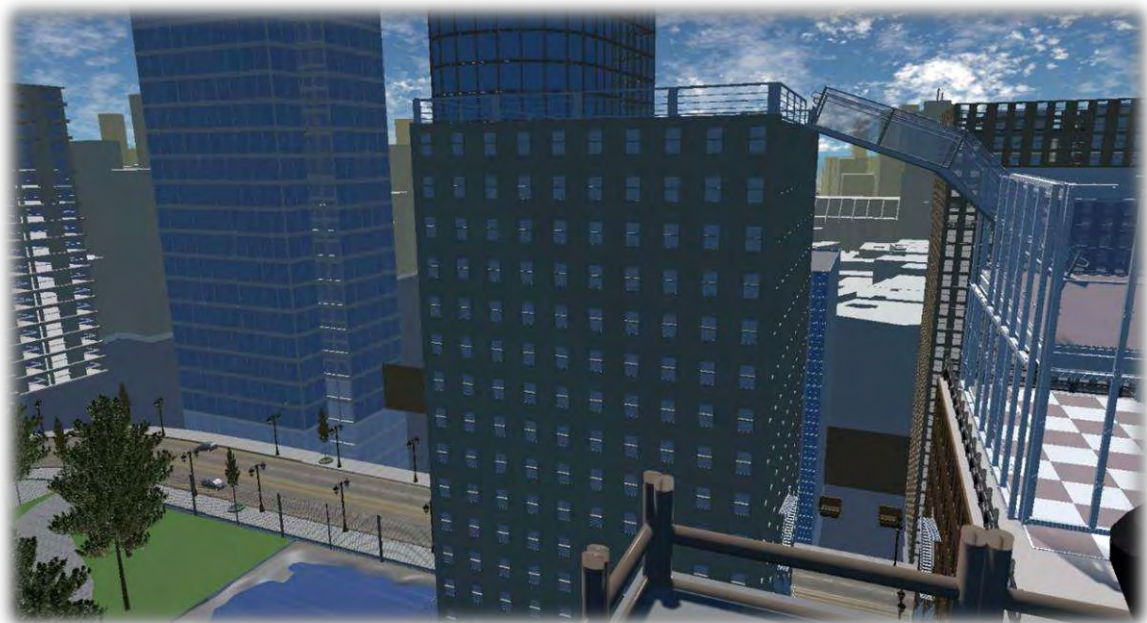


Figure 24: View from stage 3, level 2

The intensity of the vertigo effect remains consistent and mimics the 1st stage of the current level, as depicted in *Figure 25* and *Figure 26*, there are railings present and the height of the building is among the lowest in the route that the user needs to follow.



Figure 25: Vertigo effect un-zoomed, level 2, stage 3



Figure 26: Vertigo effect zoomed, level 2, stage 3

Figure 27 depicts the bridge/passage to the final building of the 2nd level. At this point, the user is at the closest distance to the ground and positioned centrally within the scenery. The helping message of that level begins to fade in (*Figure 28*).

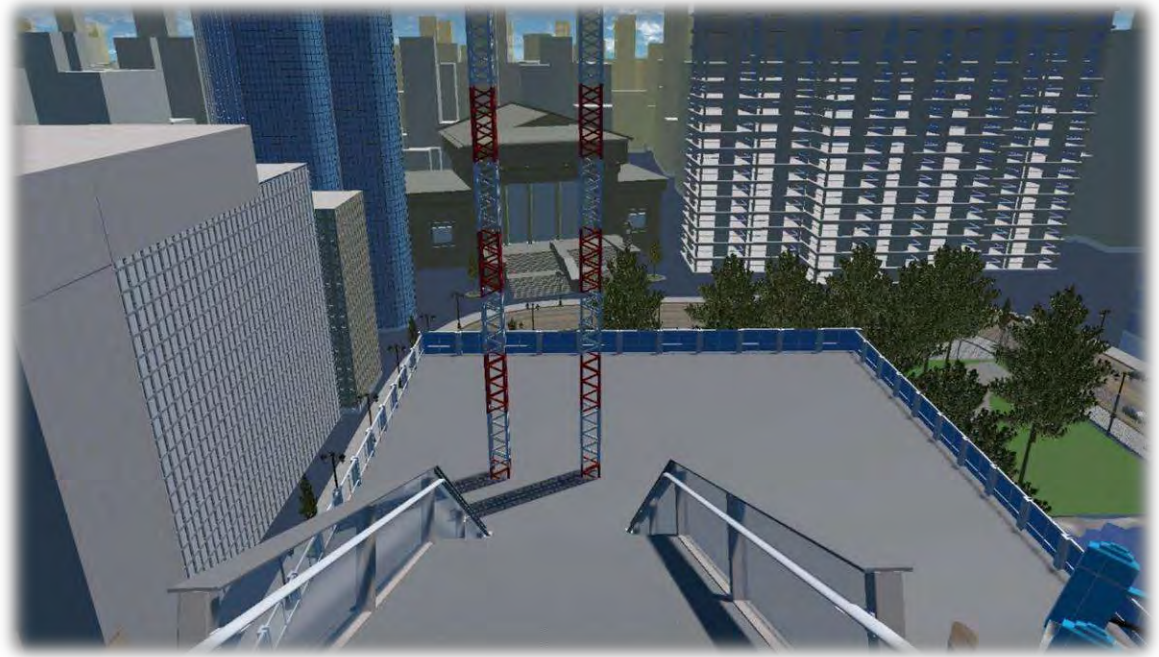


Figure 27: Passage to the next stage

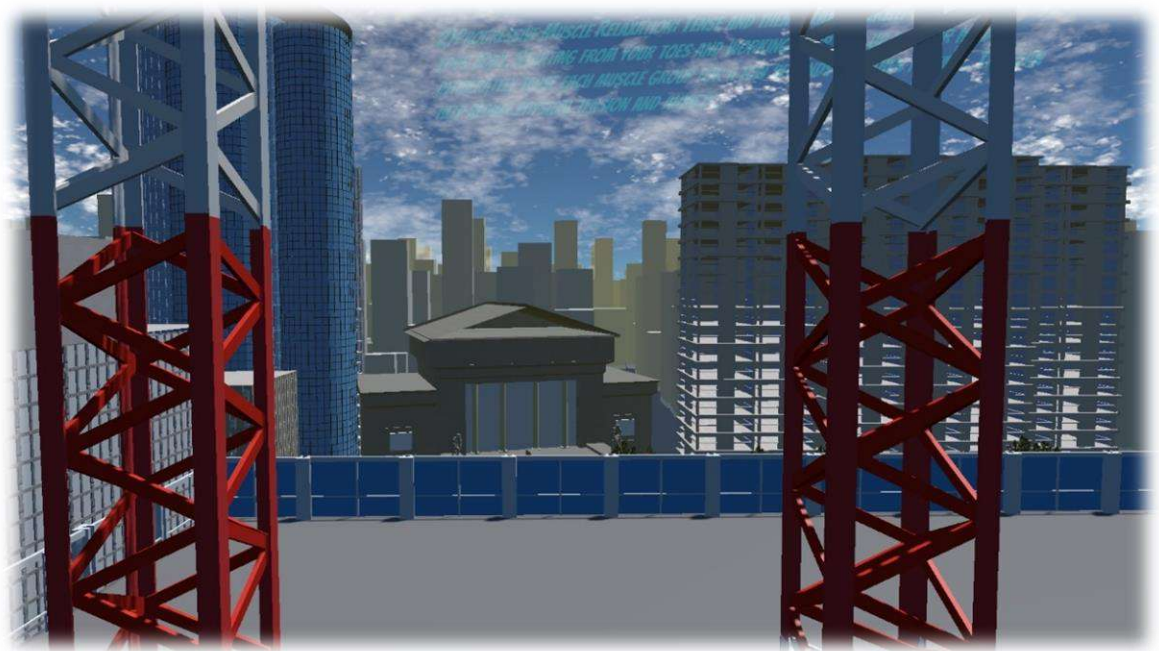


Figure 28: View from stage 4, level 2

The helping message of that level advises the user about a muscle relaxation technique, which is within the same category as the deep breathing technique from the 1st level message. *Figure 29* also displays the 1st helping message, albeit not in detail. The user can now combine the two techniques for better rehabilitation results, while also gaining motivation to continue and reach the next final stages of the levels for the helping message to appear.

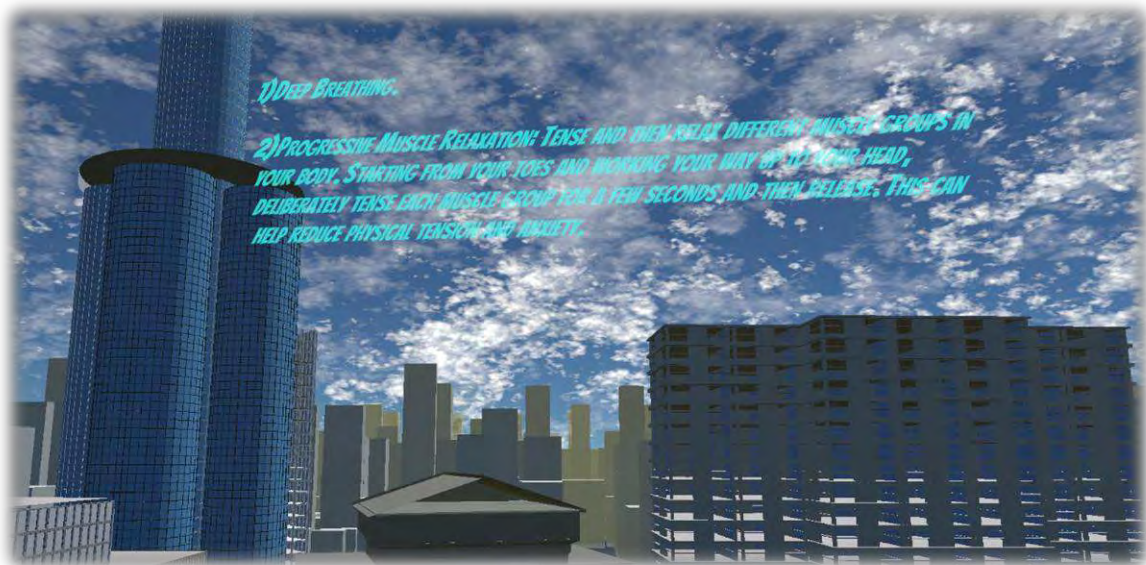


Figure 29: Helping message, level 2

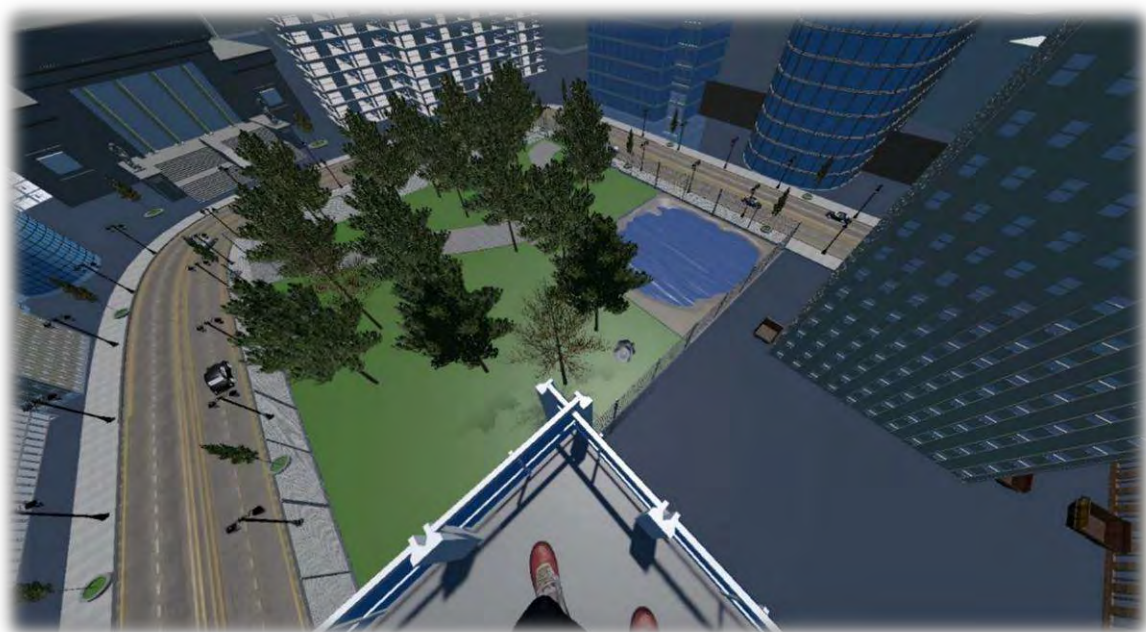


Figure 30: Vertigo effect level 2, stage 4

At this point (*Figure 30, Figure 31*), the intensity of the effect is the lowest because the user is currently at the lowest height structure. The dolly effect focuses on the dynamic moving lake within the park. On the other hand, the traffic noises are at maximum volume, enhancing the immersion and simulating the most common exposure experienced in everyday life.

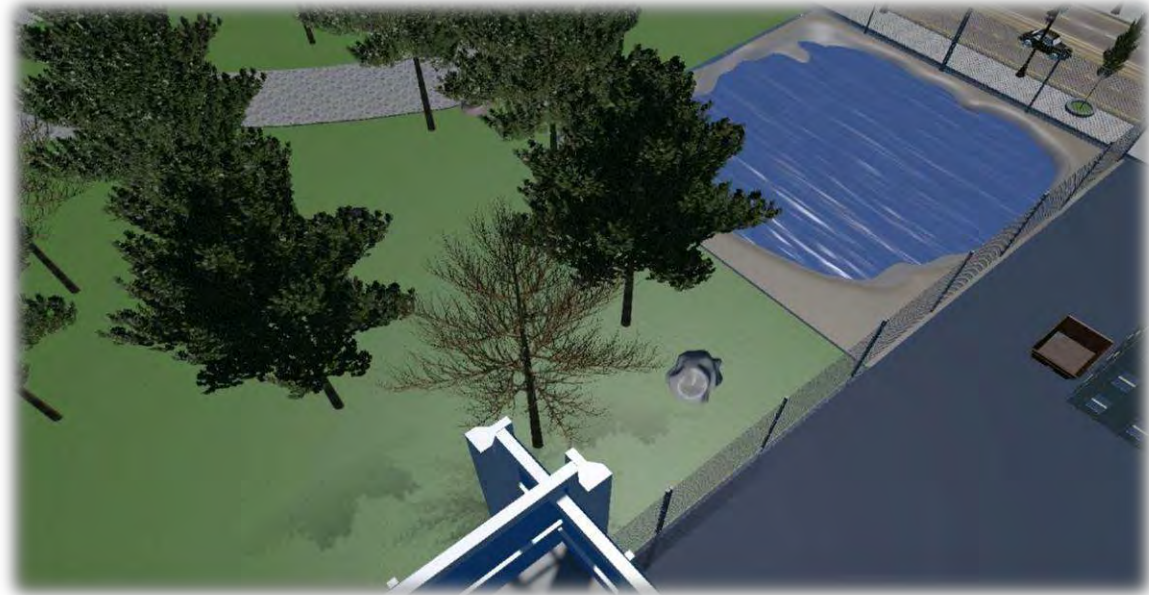


Figure 31: Vertigo effect level 2, stage 4

The figure below (*Figure 32*) indicates the end of the 2nd level and the start of the 3rd level through the passage/bridge.



Figure 32: Passage to level 3

4.3.3 Level 3

Level 3 begins with a view of a 2-storey structure enclosed by glass walls (*Figure 33*), resembling a rooftop house commonly found in areas featuring restaurants, bars, and shops. These establishments offer elevated views, providing a sense of height and scale.

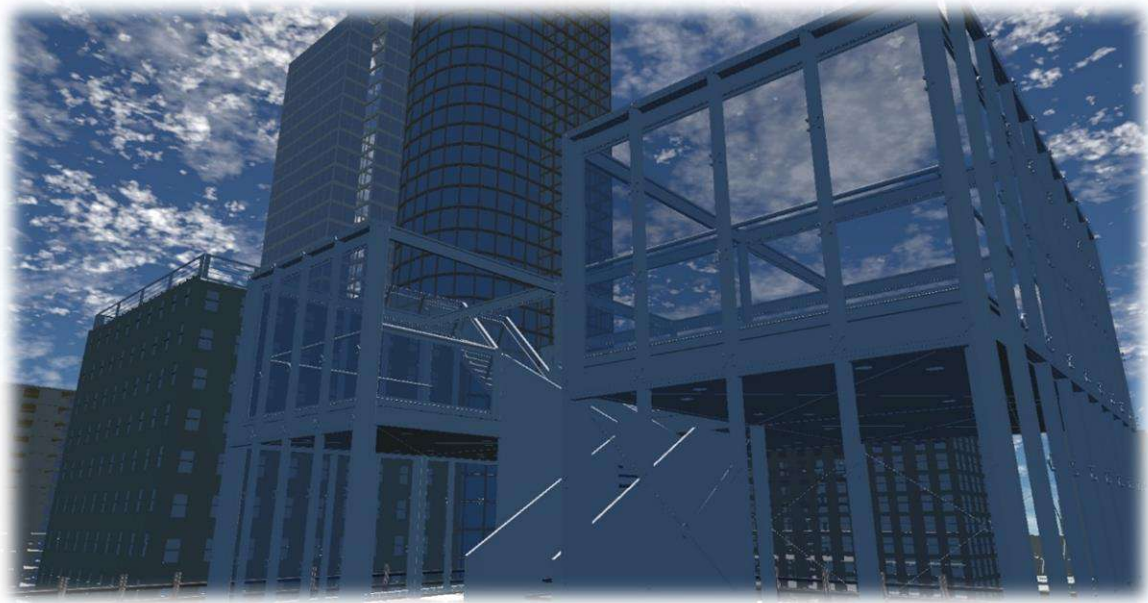


Figure 33: View at level 3 stage 1

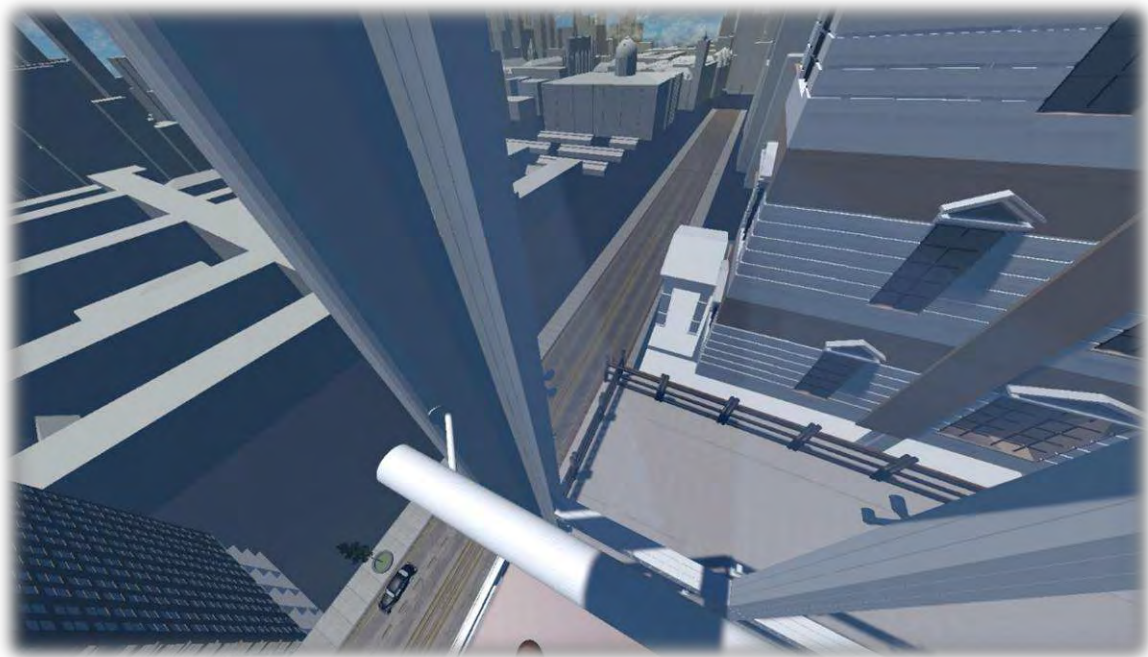


Figure 34: Vertigo effect un-zoomed level 3, stage 1

It is worth mentioning that at this point, the vertigo effect (*Figure 35, Figure 36*) is triggered only on the side of the building facing the road, and the trigger point is positioned very close to the glass. This implemented mechanic aims to provide the user with the feeling that even though they are close to the edge, they are protected by the glass barrier.

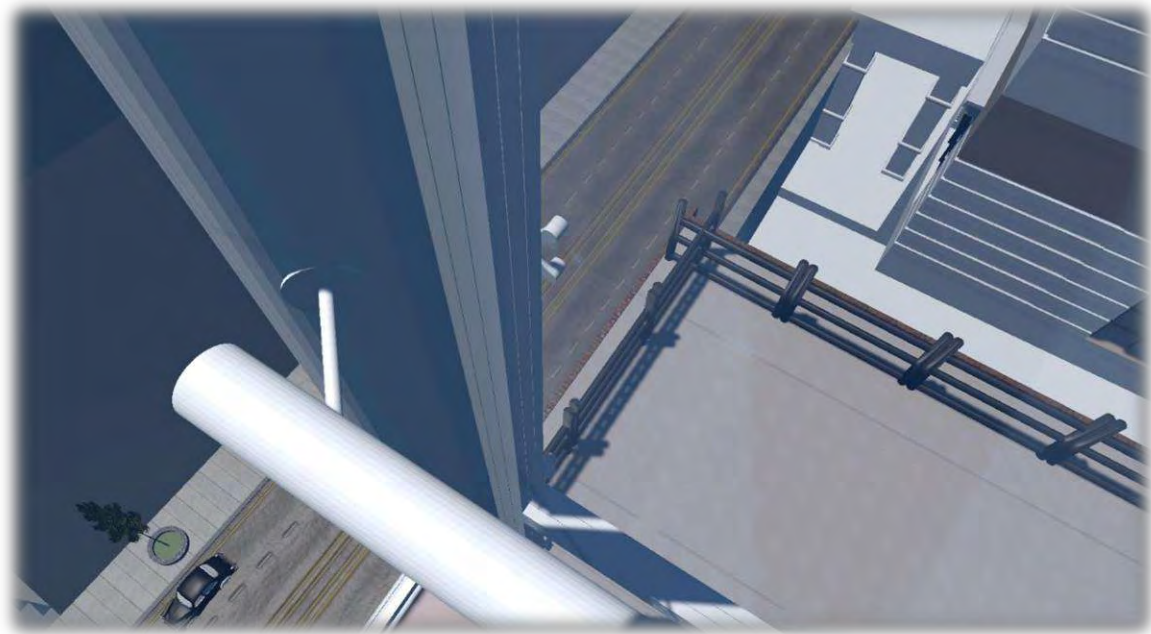


Figure 35: Vertigo effect zoomed level 3, stage 1

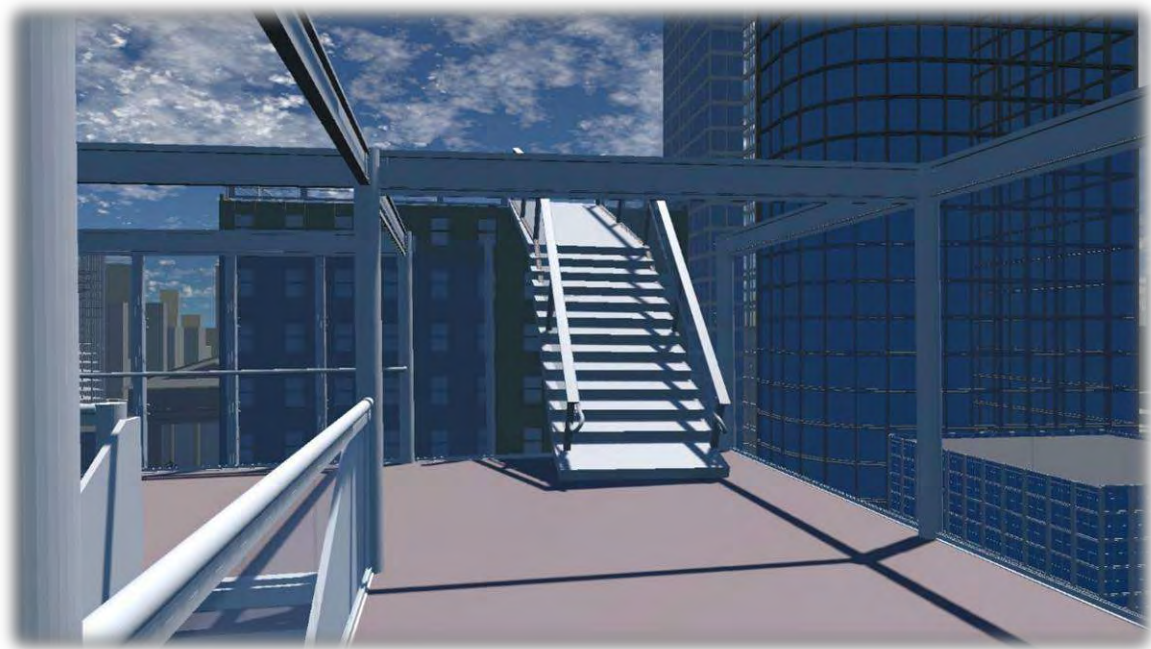


Figure 36: Passage to next stage

As the user passes through the passage/bridge depicted in *Figure 36*, they arrive at the second and final stage of Level 3, marking the conclusion of the level and the end of structures of medium height. At this juncture(*Figure 37*), the user observes two messages fading in: the helping message specific to this level and the message indicating the requirement for further progression.

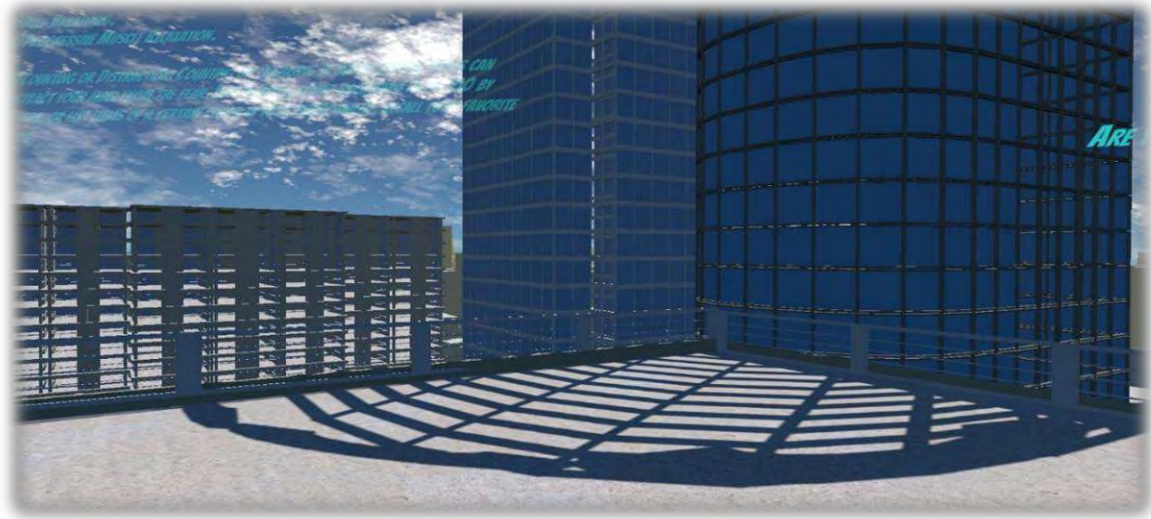


Figure 37: View from level 3 stage 2

The message presented at this level (*Figure 38*) pertains to distraction methods. As mentioned in the future steps section (*below*), at this point the user is allowed to tune in to their favorite music and combining this technique with the two previous ones can assist the user in better managing their stress levels.



Figure 38: Helping message at level 3

The dolly effect follows a similar pattern (Figure 39, *Figure 40*) to the final stage of level 2 but in a significantly higher position. The focal point remains the center of the scenery, namely the park and the lake. However, in this instance, the user is listening to their favorite music as advised in this stage's message. This implementation choice aims to balance the level of stress experienced at this stage with that of the previous ones, despite the increased height.

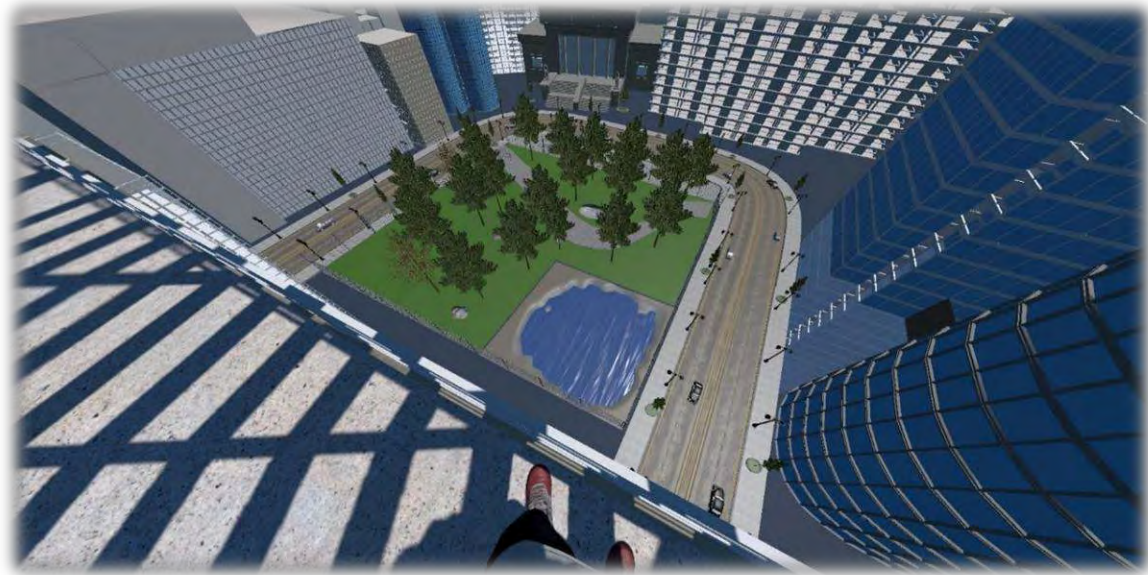


Figure 39: Vertigo effect un-zoomed at level 3, stage 2

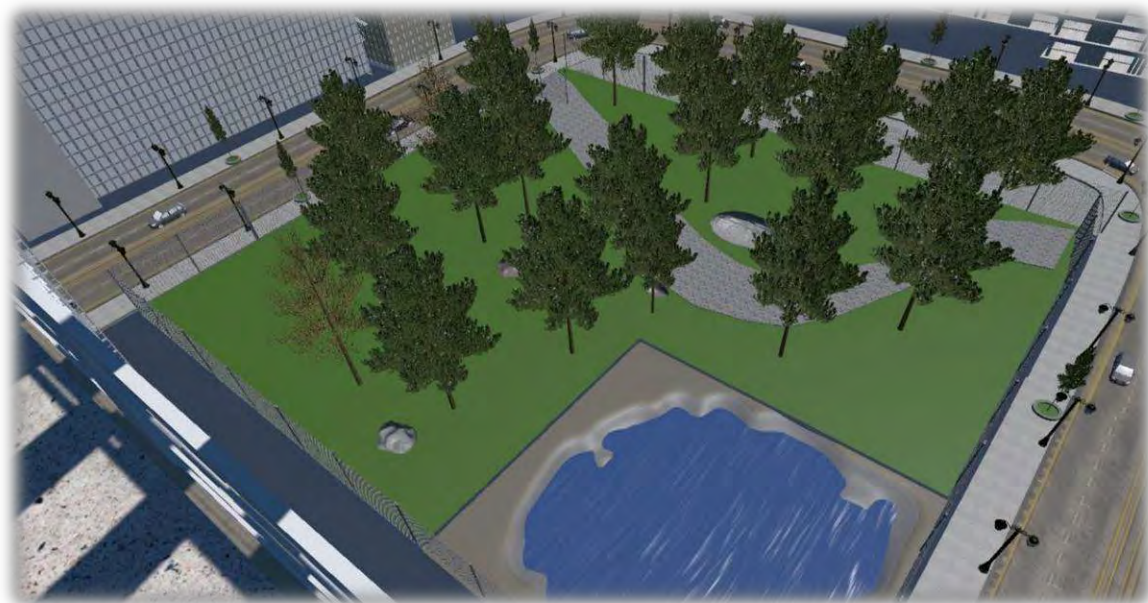


Figure 40: Vertigo effect zoomed level 3, stage 2

The second message appearing at this stage (*Figure 41*) asks the user if they are ready for the next step, with the background showcasing the skyscrapers, indicating the progression. The requirement is simply to press the R key on the keyboard. It's worth noting that the music from this level will continue playing throughout the rest of the walkthrough, as the next levels are considerably more challenging.



Figure 41: Passage/Message to the next level

4.3.4 Level 4

After pressing the R button, the user is teleported to the top of the skyscraper (*Figure 42*). Here, they can clearly hear the ambient sounds of the air and notice that the lower level of the clouds is significantly lower than their current position. Additionally, they can see the entire scenery, including the outside structures that are not included in the walkthrough.

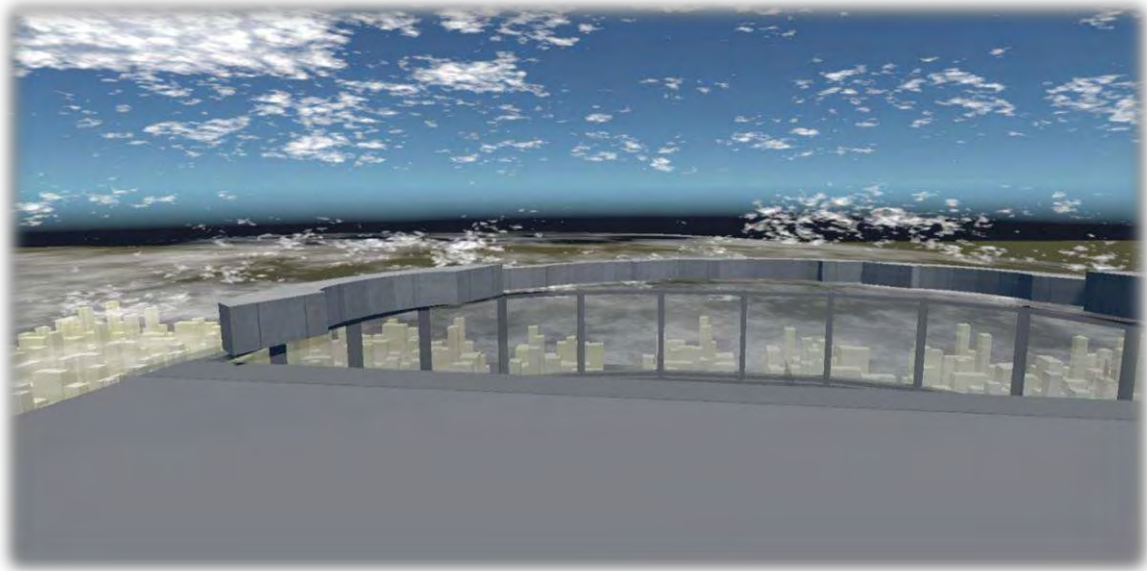


Figure 42: View from level 4 stage 1/ Skyscraper

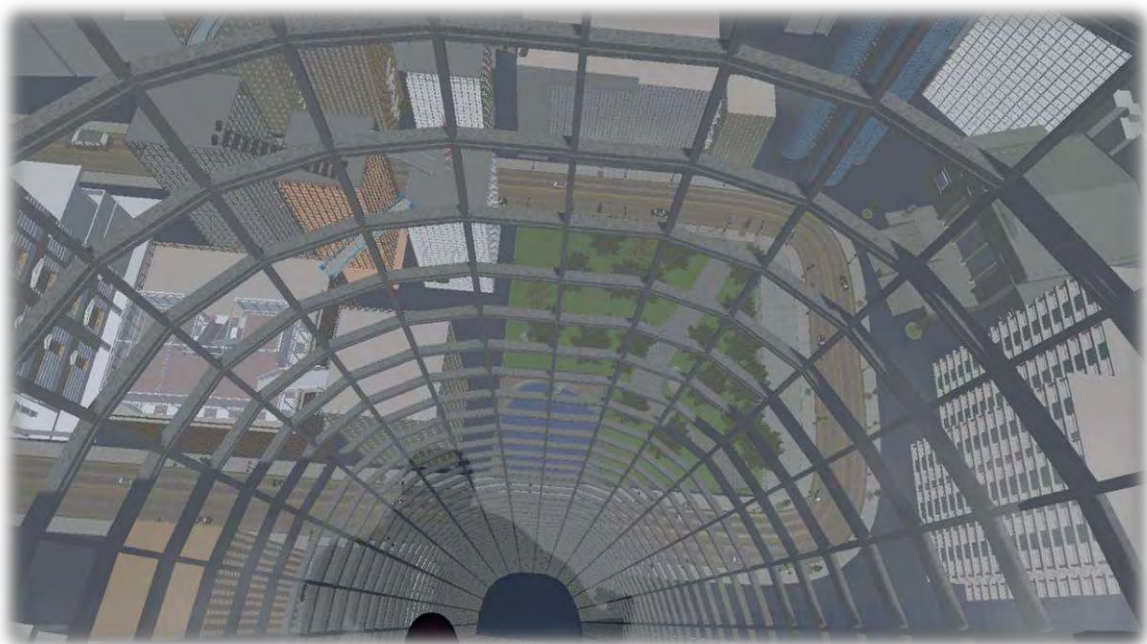


Figure 43: View from the glass floor on skyscraper

The skyscraper, as shown in *Figure 43*, has half of its floor made of transparent material, allowing the user to see the base of the building and offering the sensation that they are literally walking on air. Additionally, the intensity of the vertigo effect at this level is at its peak. As depicted in *Figure 44* and *Figure 45*, the entire scenery that the user interacted with from level 1 to level 3 appears tiny in their eyes. It's important to note that the pictures were taken for demonstration purposes only, and there is no expectation for the user to approach so close to the edge, not even after multiple runs of the playthrough.

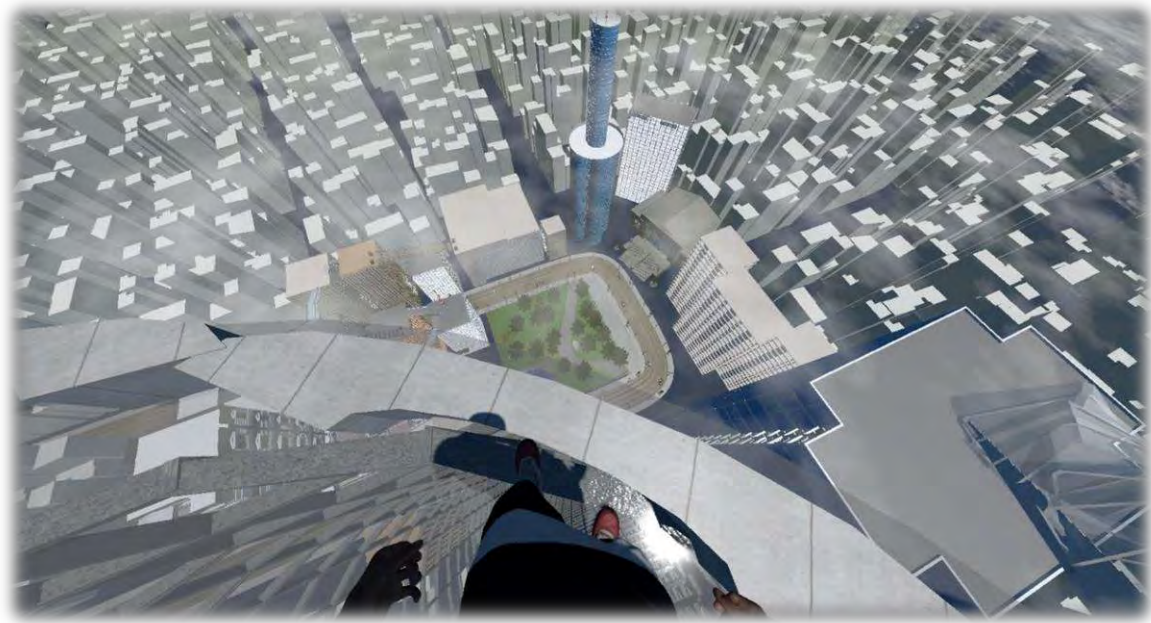


Figure 44: Vertigo effect un-zoomed level 4, stage 1

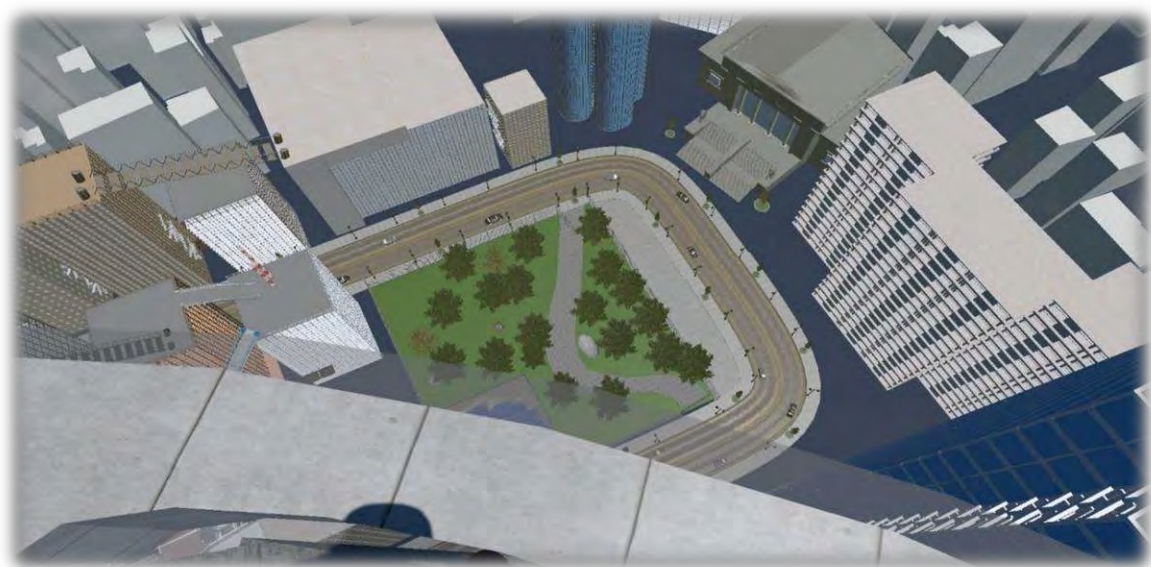


Figure 45: Vertigo effect zoomed level 4, stage 1

The passage/bridge to the next skyscraper and the final stage of level 4 is shown in *Figure 46*, with the crossing depicted in *Figure 47*. The user moves through the clouds, but the closed bridge provides a sense of safety, enhancing the immersive experience. At this level, level 4, the scalability of the project is at its peak and may not be suitable for every user, as previously mentioned.

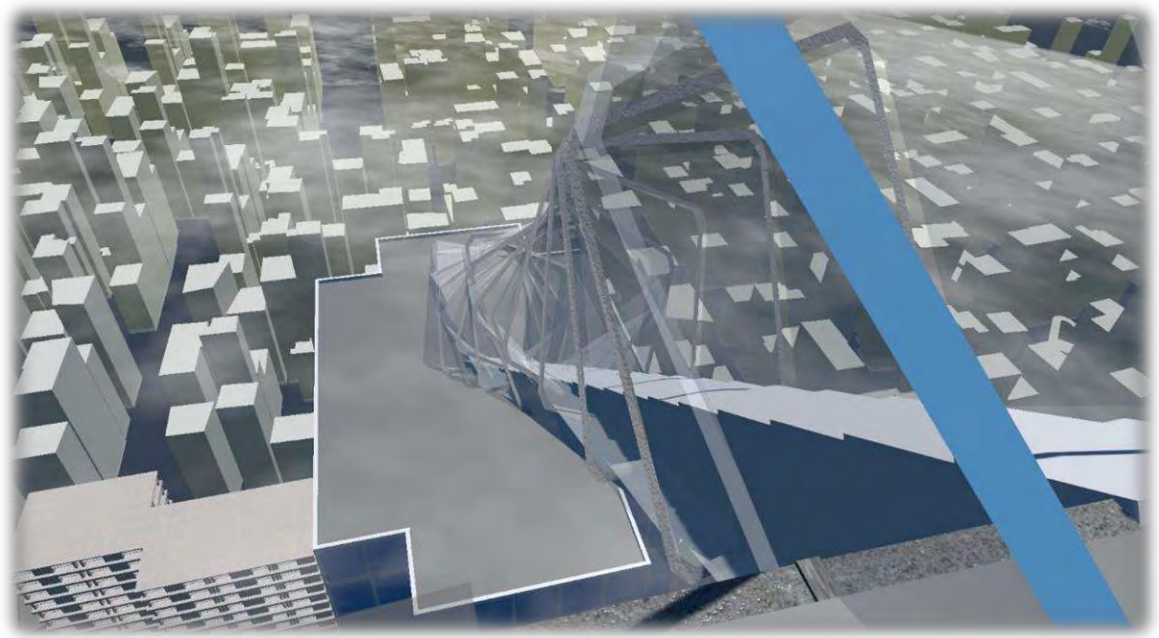


Figure 46: Passage to next stage/ Glass bridge

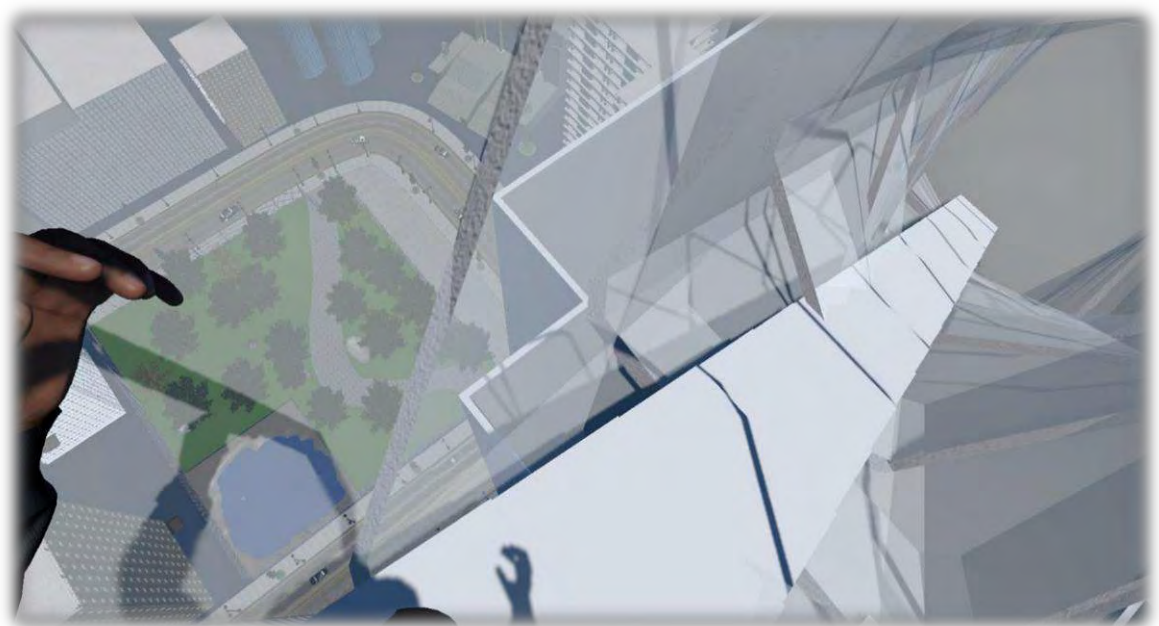


Figure 47: View from inside the bridge

Arriving at the 2nd skyscraper (*Figure 48*), the same pattern repeats, with two messages starting to fade in, and the view of the whole scenery also visible. The helping message displayed in *Figure 49* suggests the user visualize a safe place for themselves, which is a perfect match considering the fearful position they are currently in.

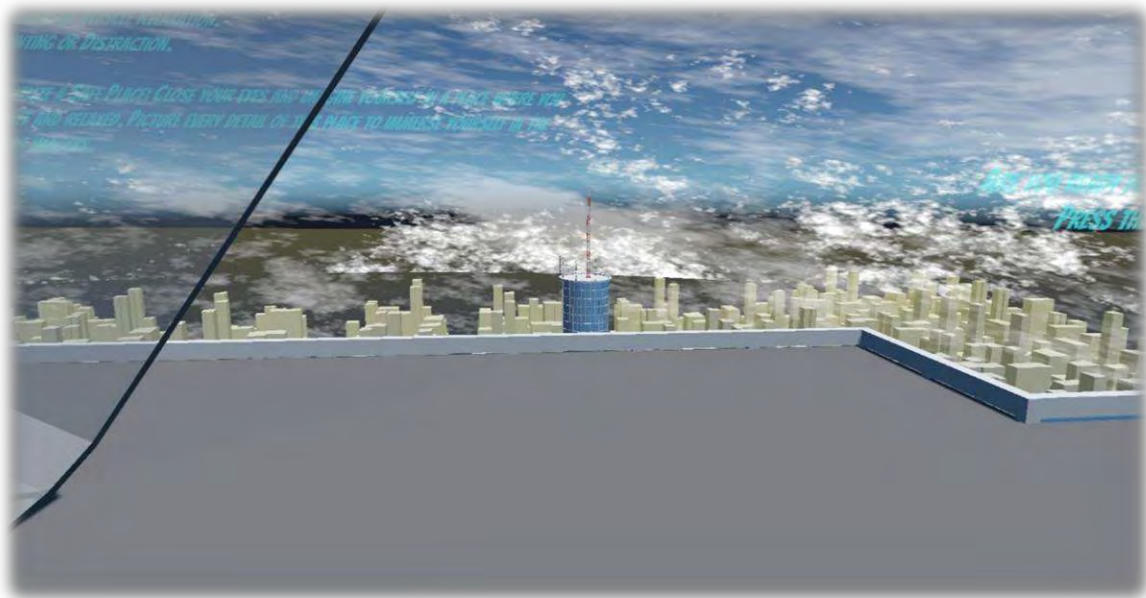


Figure 48: View from level 4 stage 2



Figure 49: Helping message level 4

It's worth mentioning that the area where the vertigo effect is triggered almost instantly upon arriving at the level through the bridge, and the intensity is at the same scale as the previous skyscraper (*Figure 50, Figure 51*).

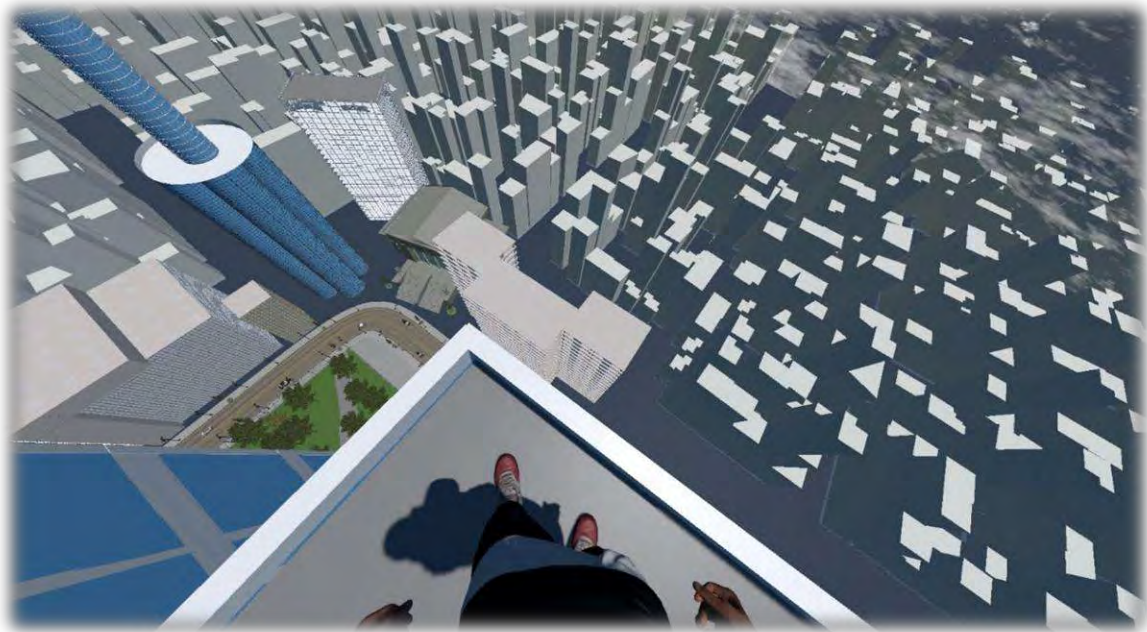


Figure 50: Vertigo effect un-zoomed level 4, stage 2



Figure 51: Vertigo effect zoomed level 4, stage 2

The other message displayed at this level is a question to the user asking if they are ready for the final stage of the game and suggesting to press the T button (*Figure 52*).



Figure 52: Passage/message to level 5

4.3.5 Level 5

Upon pressing the T key, the user is teleported again to a significantly taller building than the stages of levels 1 to 3 but shorter than the skyscrapers (*Figure 53*). The unique aspect of this building is that it is narrow, not giving the user much room to move freely. At this point, the field of view encompasses all the previous levels, allowing the user to observe the progress they have made so far.

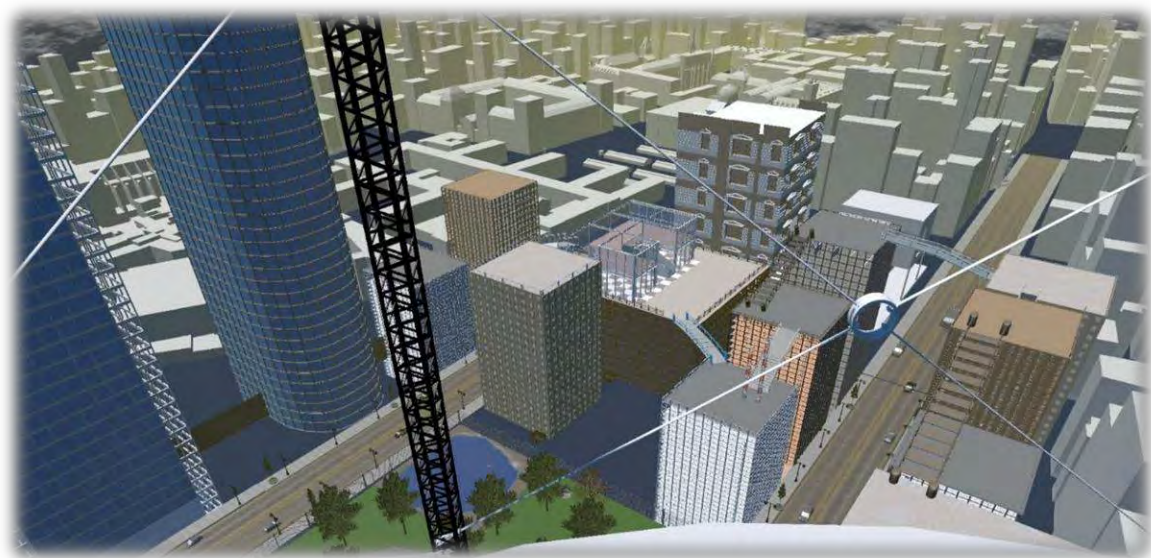


Figure 53: View from level 5

The vertigo effect is also pronounced at this stage, but it also provides a sense of safety to the user due to the absence of tall railings close to them (see *Figure 54* and *Figure 55*).

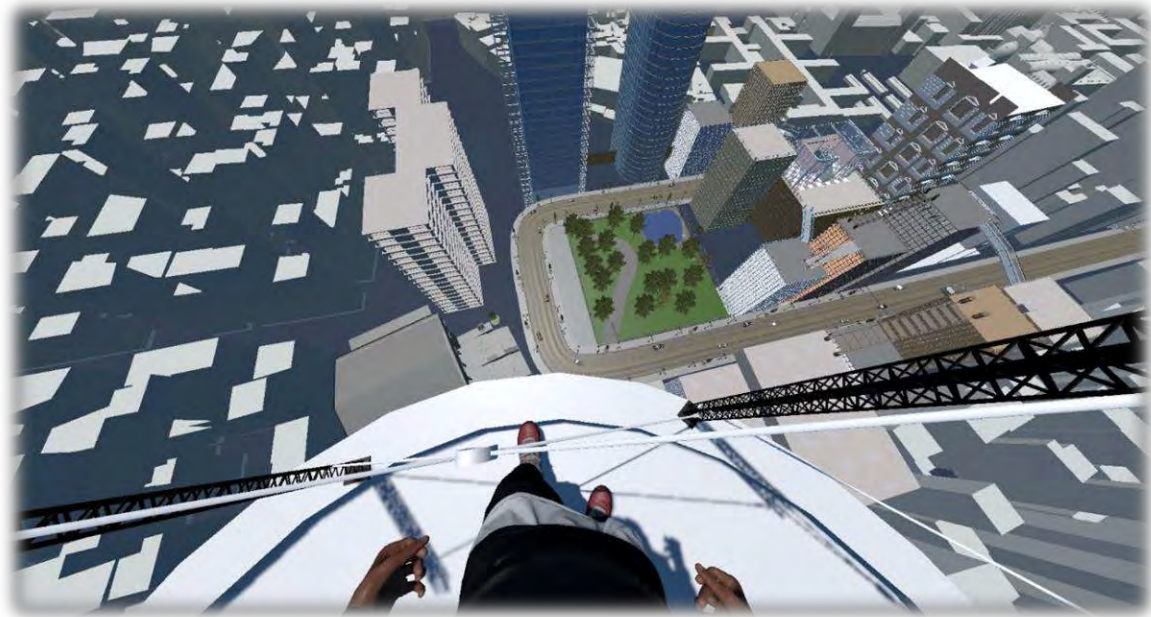


Figure 54: Vertigo effect un-zoomed level 5

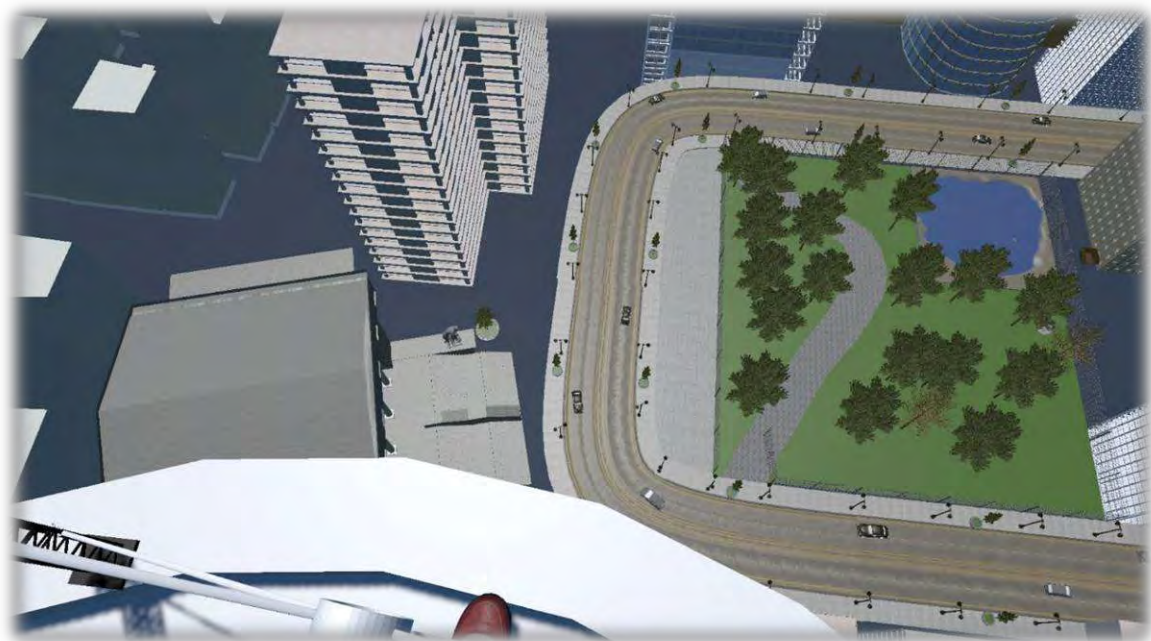


Figure 55: Vertigo effect zoomed level 5

The final message of the game combines the last helping message provided during the playthrough, which emphasizes the importance of having an exit plan strategy in every fearful situation, including heights. This message is combined with the acknowledgment that the user has completed all stages of the walkthrough, and they are provided with the exit button as their current exit plan (Figure 56).



Figure 56: Helping message at level 5/ Exit message/Completion

4.4 Scripts

This chapter provides essential figures detailing the creation and features of the serious game. It explains how the vertigo effect is generated through scripts attached to in-game objects, the mechanisms for triggering and deactivating this effect, and the fade-in and fade-out behavior of the in-game interface. Additionally, it covers the rotation of the interface in coordination with the player's movement within the game scene.

```
if (isDollyIn)
{
    // Smoothly adjust the camera FOV towards the target FOV
    float targetFOVChange = targetFOV - initialFOV;
    float t = Mathf.PingPong(Time.time * dollySpeed, 1f);
    float easedT = SmoothStep(0f, 1f, t); // Apply smoothing
    currentFOV = initialFOV + targetFOVChange * easedT;

    // Apply limits to FOV
    currentFOV = Mathf.Clamp(currentFOV, minFOV, maxFOV);
    virtualCamera.m_Lens.FieldOfView = currentFOV;

    // Move the virtual camera closer to the humanoid smoothly
    Vector3 targetPosition;

    if (humanoidTransform == null)
        targetPosition = transform.position + transform.forward * dollyDistance;
    else
        targetPosition = humanoidTransform.position + humanoidTransform.forward * dollyDistance;

    virtualCamera.transform.position = Vector3.Lerp(virtualCamera.transform.position, targetPosition, Time.deltaTime * dollySpeed);
}
else
{
    // Reset to initial FOV and position when not dolly-in
    virtualCamera.m_Lens.FieldOfView = Mathf.Lerp(virtualCamera.m_Lens.FieldOfView, initialFOV, Time.deltaTime * dollySpeed);
    virtualCamera.transform.localPosition = Vector3.Lerp(virtualCamera.transform.localPosition, Vector3.zero, Time.deltaTime * dollySpeed);
}
}
```

Figure 57: Vertigo effect script

The event to trigger the effect *Figure 58* and the event to deactivate it *Figure 59*.

```
private void OnTriggerEnter(Collider other)
{
    if (other.CompareTag("Obstacle"))
    {
        Debug.Log("OnTriggerEnter: Obstacle entered");
        isDollyIn = true;
        if (globalVolume != null)
        {
            if (depthOfFieldEffect != null)
            {
                depthOfFieldEffect.active = true;
            }
        }
    }
}
```

Figure 58: Script the triggers the vertigo effect

```
private void OnTriggerExit(Collider other)
{
    if (other.CompareTag("Obstacle"))
    {
        Debug.Log("OnTriggerExit: Obstacle exited");
        isDollyIn = false;
        currentFOV = initialFOV;
        if (globalVolume != null)
        {
            if (depthOfFieldEffect != null)
            {
                depthOfFieldEffect.active = false;
            }
        }
    }
}
```

Figure 59: Script that deactivated the vertigo effect

The visibility of the canvas when the player approaching the in games interface position.

```
void Update()
{
    // Calculate the distance between the player and the canvas text
    float distance = Vector3.Distance(player.position, transform.position);

    // Calculate the alpha based on the distance
    float alpha = 1f;

    if (distance > maxDistance)
    {
        alpha = 0f; // Fully invisible when far away
    }
    else if (distance > minDistance)
    {
        // Linearly interpolate between invisible and fully visible based on distance
        alpha = 1f - (distance - minDistance) / (maxDistance - minDistance);
    }

    // Set the canvas text's alpha
    SetTextAlpha(alpha);
}

// method to set the alpha value of the canvas text
private void SetTextAlpha(float alpha)
{
    Color textColor = canvasText.color;
    textColor.a = alpha;
    canvasText.color = textColor;
}
}
```

Figure 60: Script for the rotating interfaces of the messages

The parameters menu change for vertigo effect in every level and for future runs making it capable of scaling in users comfort level.

Vertigo Effect (Script)	
Script	VertigoEffect
Player	Player
Target FOV	100
Min FOV	50
Max FOV	100
Dolly Speed	0.3
Dolly Distance	5
Velocity Multiplier	1.5

Figure 61: The vertigo effect variable scalability

4.5 Future steps and Implementations

As previously mentioned, the application is still in the prototype stage and includes only a few design ideas. There are various steps designed to be implemented both inside and outside of the game. One such feature is the character/avatar wearing headsets, which serves the main purpose of enabling the user to connect with an expert in the field of acrophobia, such as a psychologist. This expert would accompany the user throughout the entire walkthrough, providing real-time advice and tips.

Another idea that has yet to be included is the implementation of a questionnaire to be filled out before and after the completion of the game. The questionnaire would contain questions measured on a scale from 0 to 10, indicating the level of fear/stress experienced by the user at different stages of the game and across multiple walkthroughs. This addition would provide a measurable variable for psychologists to consider and adjust their approach accordingly. In addition, if the user reaches level 3 of the game where the helping messages display distraction advice, it can enable the user to start listening to their favorite music. Music plays a significant role as a helpful tool for distraction, enhancing the user's ability to cope with the challenges presented in the game.

The feeling of immersion and interaction with the environment can be further enhanced through the use of a wireless wearable gaming control utilizing brain-computer interface (BCI) technology. This device communicates directly with the brain through electroencephalographic (EEG) signals, allowing for a more seamless and intuitive gaming experience. The overarching goal of further development and implementations is to streamline the app, making it as user-friendly and accessible as possible while ensuring it provides helpful guidance and support at every stage.

Utilizing a useful tool from the project management field, a Gantt Chart is displayed in *Figure 62*, representing the exact steps and orientation of the work focus to accomplish the aforementioned future steps within the represented deadlines.

	A	B	C	D	E	F	G
1	Future Development Gantt Chart	Quarter 1 - 2024	Quarter 2 - 2024	Quarter 3 - 2024	Quarter 4 - 2024	Quarter 1 - 2025	Quarter 2 - 2025
2	Step 1: Development of music listening through integrating Spotify						
3	Step 2: Development of new cognitive mechanism						
4	Step 3: Development of interaction with Psychologist						
5	Step 4: Development of new traffic simulation						
6	Step 5: Development of using through simulink						
7							
8							
9							
10							

Figure 62: Gantt Chart for future steps

5. Conclusion

In concluding this dissertation, I reflect on my dual role as both the developer and sole user of the Unity-based acrophobia treatment app, designed to offer a first-person perspective experience for individuals grappling with fear of heights. This unique perspective, rooted in personal experience, sheds light on the effectiveness and nuances of the application. Developing this app was not only a technical endeavor but a personal journey. As an acrophobic individual, I navigated the intricate balance between addressing the needs of potential users and crafting an experience that would resonate with my own acrophobia.

The challenges faced during development underscored the importance of meticulous design choices, each informed by my own understanding of acrophobia. Using the app as an acrophobic individual provided firsthand insights into its impact on anxiety levels and acrophobia symptoms. The first-person perspective, coupled with exposure therapy principles, facilitated a gradual confrontation of fear-inducing scenarios. I observed notable reductions in anxiety levels and perceived changes in my acrophobia symptoms, suggesting promising therapeutic potential.

The app's ability to engage users was a key consideration. My personal experience reinforced the significance of creating an environment that not only triggers fear but also provides a controlled and adaptable space for users to confront their fears at their own pace. The first-person perspective proved to be a powerful tool in fostering a sense of presence and immersion. From a developer's standpoint, each design choice was made with acute awareness of the acrophobic experience. The virtual environments, scenarios, and user interactions were carefully crafted to align with exposure therapy principles.

My personal acrophobia journey influenced decisions that aimed to strike a balance between challenge and support, creating an experience that is both therapeutic and engaging. The app's adaptability to individual responses emerged as a key strength. Personalization of the experience, based on user feedback and reactions, contributed to a sense of agency and control. The potential for individualized treatment within the app presents exciting possibilities for tailoring interventions to the specific needs of acrophobic individuals. It is imperative to acknowledge the limitations of this study, given the singular nature of my

personal experience. Future research endeavors should involve a diverse group of participants to validate and generalize these findings. Additionally, ongoing iterations of the app should be informed by collective insights to enhance its efficacy.

When comparing this application with other existing applications mentioned in Chapter 2.4 (pg. 7), it is important to note that some of them aim to assist users with their acrophobia. However, existing applications lack visual feedback mechanics. A major advantage of this application is the implementation of the vertigo effect visual effect, which scales depending on the level and the user's progression. Additionally, the integration of real-world noises such as wind and traffic enhance the immersive experience and give a close representation of real-life scenarios.

In conclusion, this Unity-based acrophobia treatment app represents a promising intersection of technology and mental health. The synthesis of personal experience, technical innovation, and therapeutic principles paves the way for continued exploration and refinement. I encourage researchers and practitioners to delve into further testing, embracing the potential of virtual reality applications in mental health interventions.

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