

Virtual Reality Game for Heatwave Awareness and Mitigation

Abstract

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Abstract		
<p>This thesis presents the development of a virtual reality (VR) game that simulates a city environment where players engage in simple, yet engaging missions designed to raise awareness about climate change and its effects. Through interactive gameplay, players learn about the impact of heat waves on cities and discover how small, strategic changes can significantly improve urban resilience. The game aims to educate and inspire action by demonstrating how individual efforts contribute to a more sustainable and liveable urban future. By leveraging VR's immersive capabilities, the project seeks to enhance engagement and understanding, making climate education more accessible and impactful.</p>		
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Virtual Reality, Heat waves, Global warming, Urban heat island effect, Immersive, Awareness, Interactive, Education, Cities		

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1 Introduction

Global warming has become an increasingly pressing issue in recent years, with growing concern worldwide. Today, it stands as a challenge that affects all of humanity, as its consequences have become more visible and impactful than ever before. One of the most critical effects of climate change is the intensification of heatwaves during the summer months, a phenomenon that now affects millions of people, especially those living in large urban areas. This thesis explores an innovative approach to raising awareness about this issue by developing a virtual reality (VR) game. The project aims to raise awareness about the reality of extreme heat by placing the player in a virtual environment inspired by hot urban areas and highlighting small actions that can contribute to mitigating its impact.

To give proper context to the project, the theoretical part of this thesis focuses on two main topics: climate change and virtual reality. It starts by defining climate change and heatwaves, exploring how cities address rising temperatures, and reviewing existing VR projects related to environmental awareness. It then introduces virtual reality with a brief overview of its history and capabilities, ending with a look at how VR is used in education, an aspect closely tied to the goals of this project. This background helps support the development decisions and gives a solid foundation for understanding the application's purpose.

The practical part of the thesis presents the various design and development decisions made throughout the entire creation process of the game, Cool the City. It also examines the technical aspects involved in building the application. Overall, this section aims to justify these choices and show how they supported the effective communication of the game's core message.

All things considered, through the development of a game, this thesis presents a non-conventional and original approach to addressing a significant issue in today's society: climate change. At the same time, it explores the potential of virtual reality in the fields of education and raising awareness.

2 Climate change

2.1 Heat waves

In 2024, unprecedented heat waves have affected numerous countries across the Americas, Europe, and Asia. Although heat waves are a normal aspect of the climate, the intensity and scale of this year's events cannot be dismissed as merely typical summer weather. Extreme heat led to tragedy in Saudi Arabia, where more than 1,000 people participating in the Hajj pilgrimage to Mecca collapsed and died. On June 17, temperatures at Mecca's Grand Mosque reached 125°F (51.8°C). In Greece, a prolonged heatwave with temperatures exceeding 100°F (38°C) for several days in June resulted in the deaths or disappearances of several tourists who went hiking in the intense heat and humidity. India also endured severe heat, with temperatures reaching around 120°F (49°C) during April and May, affecting millions—many of whom lacked access to air conditioning. (Barlow & Basara 2024.)

The World Meteorological Organization characterizes this phenomenon as at least five consecutive days during which the daily maximum temperature exceeds the average maximum temperature by 5 °C (9 °F) or greater (Rafferty 2024). The IPCC highlights that human-induced climate change has significantly increased the frequency and severity of heatwaves since the 1950s (Figure 1), with the magnitude of extreme events intensifying further with each increment of global warming (WMO 2023).

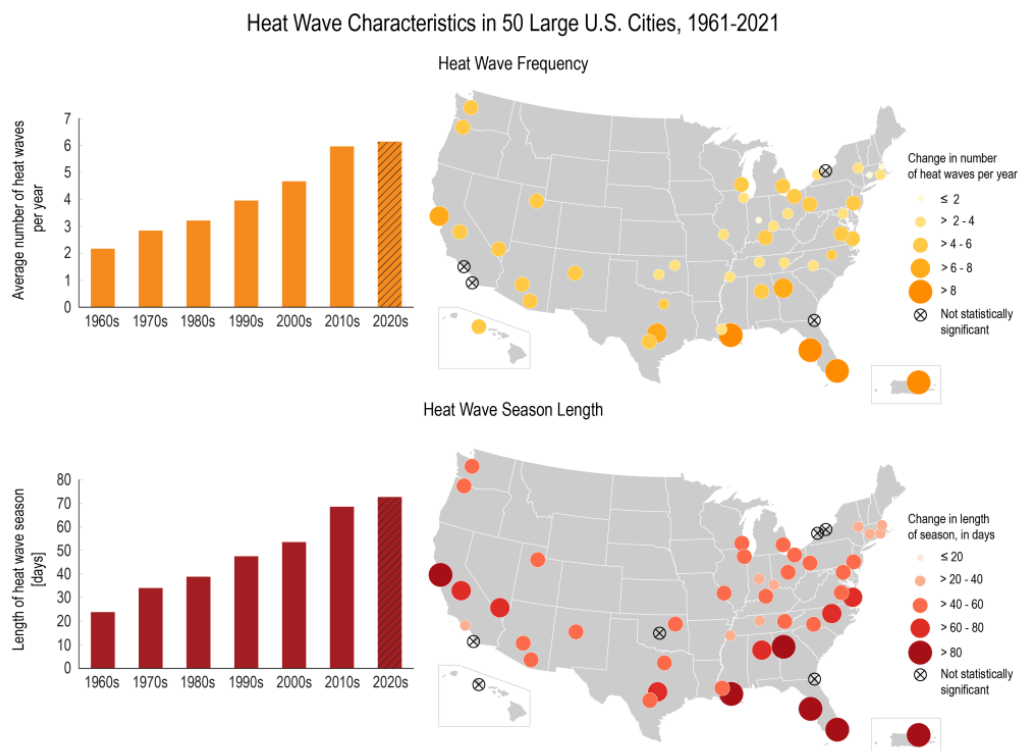


Figure 1. Heat Wave Characteristics in 50 Large U.S. Cities 1961-2021 (USGCRP 2021)

Both the frequency and duration of heatwaves have increased over time. Researchers found that the number of heatwaves rose from an average of 75 per year between 1979 and 1983 to 98 per year between 2016 and 2020. Their lifespan has also extended, lasting an average of 12 days from 2016 to 2020 compared to eight days during the earlier period. (Erdenesanaa 2024.)

Heatwaves significantly affect mortality and morbidity across all age groups (Figure 2), with the elderly and children being particularly at risk. Individuals with pre-existing medical conditions, especially those related to cardiovascular and respiratory health, are among the most vulnerable to the adverse effects of heatwaves. (Arsad et al. 2022.)

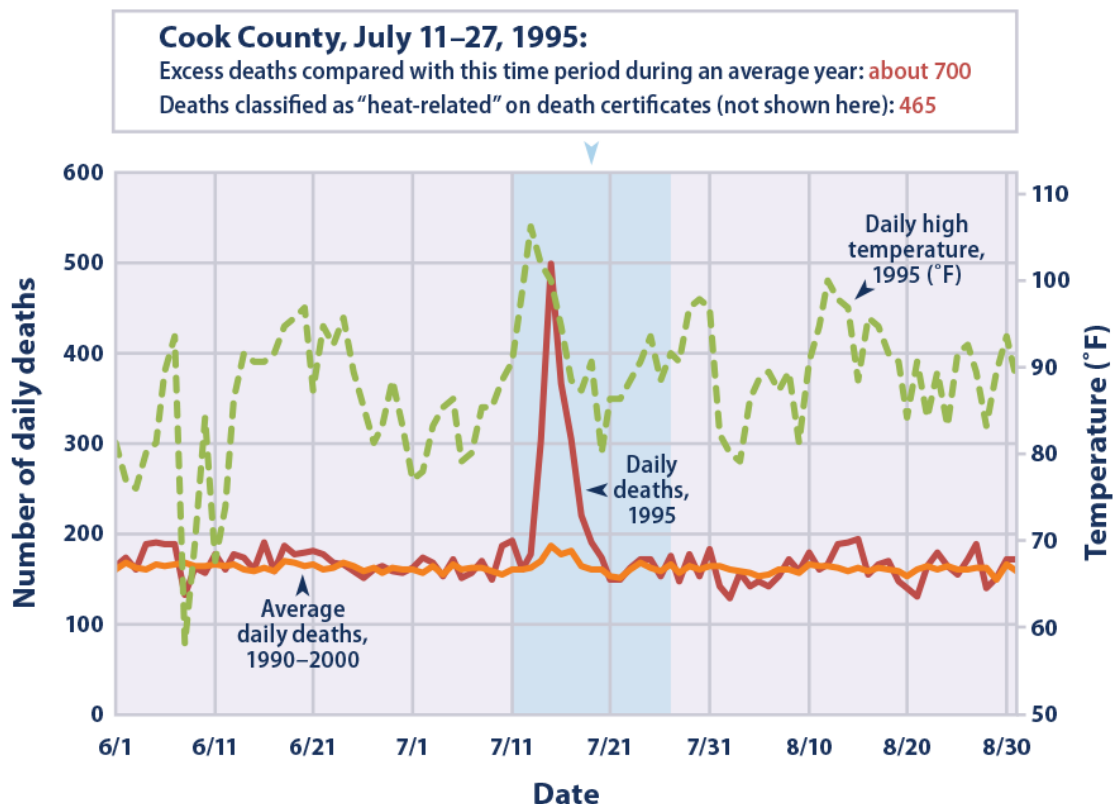


Figure 2. Heat-Related Deaths During the 1995 Chicago Heat Wave (EPA 2016)

Heat waves affect physical health and profoundly impact food security, water resources, and overall livelihoods (IRC 2024). Heatwaves also deplete moisture from soil and vegetation, damaging crops and increasing the likelihood of wildfires. (Erdenesanaa 2024).

2.2 Urban preparation for heatwaves

Cities experience heightened temperature challenges compared to rural areas, exacerbated by the urban heat island effect (Mackres et al. 2023).

The urban heat island effect (Figure 3) refers to the rise in temperature caused by the built environment. Within a city, temperatures can vary, with downtown and industrial zones typically being warmer than urban parks and low-density residential neighborhoods. (Druckemiller 2023.) The urban setting can intensify heat stress due to artificial materials and higher population density (Chen et al. 2023).

Why the urban heat island effect occurs

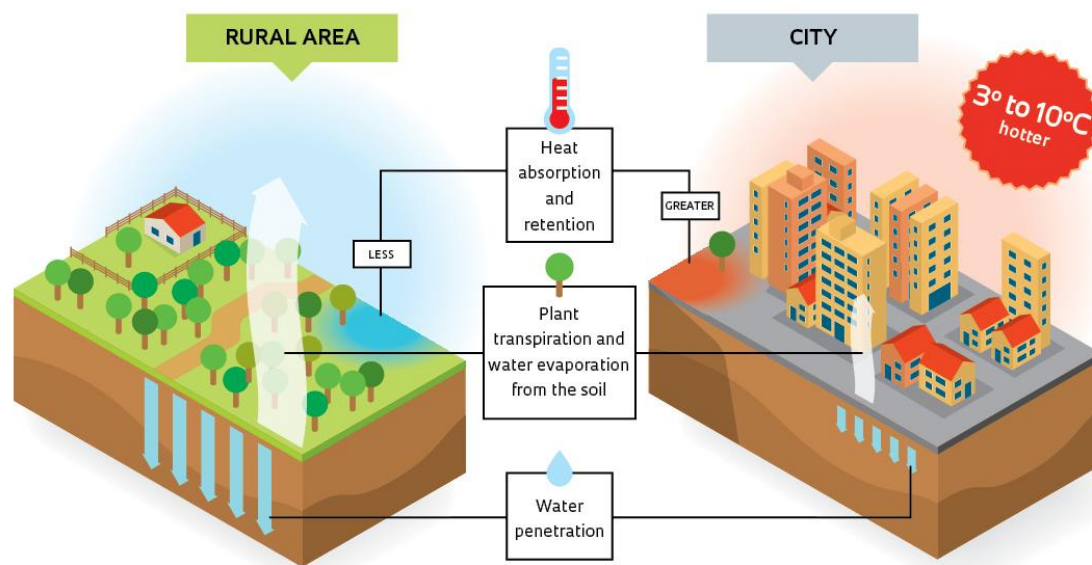


Figure 3. Urban heat island effect (Alexandre Affonso 2017)

To enhance resilience against future extreme heat events, cities can integrate strategies to mitigate urban heat islands into their long-term planning. These cooling approaches can help reduce the effects of extreme heat on public health and urban infrastructure. (EPA 2025a.)

Here are some of the solutions cities around the globe are implementing to address this issue:

- **Green areas:** Urban greening initiatives play a vital role in reducing heat exposure by mitigating extreme heat. Vegetation contributes to lower temperatures through shade provision, enhanced evapotranspiration, and the reduction of the urban heat island effect. (JRC 2023.) Medellín's \$16.3 million green corridor initiative, costing \$6.50 per person, reduced urban temperatures by 2°C while also decreasing air pollution. These tree-lined corridors (Figure 4) provide shade, promote biodiversity, and cool the city through evapotranspiration, highlighting the growing appeal of nature-based solutions for urban planning. (Thomson 2024.) Paris is addressing the heat island effect with its "Oasis Schoolyard Project," which plans to transform 770 playgrounds into shaded, tree-filled spaces by 2040. Meanwhile, Singapore is enhancing urban greenery by adding 100 hectares of green building facades, aiming to double this by 2030, and creating 50 nature paths. (Moloney 2024.)



Figure 4. Green cover has helped lower temperatures on major highways such as Oriental Avenue in Medellín (Getty Images 2023)

- **Cool rooftops:** A building gains heat from various sources, including internal activities, outdoor temperature, and solar radiation. While devices like TVs and ovens contribute to the need for air conditioning, solar radiation significantly impacts indoor temperatures. Therefore, a roof's ability to reflect sunlight and reduce heat absorption is crucial for maintaining a cooler indoor environment. (Greene 2023.) Replacing dark surfaces with lighter ones could reduce heat wave peak temperatures by 2°C or more, as darker surfaces absorb more heat. For example, fresh asphalt reflects only 4% of sunlight, natural grassland reflects up to 25%, and fresh snow reflects as much as 90%. (Pearce 2018.) Cool roof technologies include the use of cooling paints (Figure 5) and green roofs (Figure 6), both of which are intended to minimize the absorption of heat and enhance energy efficiency. Cooling paints, which frequently incorporate reflective substances such as titanium dioxide, are applied to roof surfaces in order to reflect a significant portion of sunlight, especially in regions with intense sun exposure and high temperatures. Green roofs are made up of a waterproof barrier layered with soil and various types of vegetation, which not only offer insulation and reflect as much as 70% of incoming solar heat but also serve additional purposes, such as enabling urban gardening or providing peaceful green spaces within densely populated city settings. (Brown 2023.)



Figure 5. A construction crew paints a white roof in downtown Washington, D.C. (María-José Viñas 2010)



Figure 6. View of the Acros Fukuoka Building (Yyama 2015)

- Cool pavements: Traditional paving materials, which often cover approximately 40% of urban areas, can reach peak summer temperatures as high as 65°C (150°F), contributing to the warming of the air above them. To mitigate this heat, cities can adopt lighter-colored paving materials that reflect more sunlight and reduce heat absorption. Additionally, permeable pavements, such as reinforced grass surfaces, can provide cooling effects by promoting moisture evaporation. In Japan, the Tokyo Metropolitan Government has implemented or subsidized the use of cool pavements in key areas as part of their road construction and maintenance efforts (Figure 7). Other cities that have adopted cool pavements include Paris, Los Angeles, Chula Vista, and Sydney. (C40 2019.) A preliminary study conducted in Arizona revealed that traditional paving materials like asphalt can heat up to 152°F at midday, whereas cool pavements stayed 10 to 16°F cooler on the surface. Cool pavements offer environmental and safety benefits. Permeable pavements reduce stormwater runoff by allowing water to seep into the ground, filtering pollutants, and lowering runoff temperatures to protect aquatic ecosystems. They enhance roadway safety by minimizing water spray from vehicles and improving traction through efficient

drainage. Reflective pavements improve nighttime visibility, potentially reducing energy use and lighting costs. In areas like parking lots or playgrounds, cool pavements create a more comfortable environment for people. (EPA 2025b.)



Figure 7. Roads paved with temperature suppressing pavement, July 18, 2024 in Bunkyo Ward, Tokyo (Sankei Shimbun 2024)

- Blue spaces: Rivers, streams, and canals function as natural heat sinks, helping to cool the surrounding air. Research conducted in India revealed that Lake Sukhna, located in Chandigarh, provides a cooling effect that extends up to 1,200 meters from its centre. (Garcia et al. 2024.) Blue spaces (Figure 8) play a vital role in urban environments by improving air quality and moderating temperatures, helping to counteract the urban heat island effect. These areas also promote mental well-being by offering a calming escape from city life and fostering social connections through shared leisure and community activities spaces. Water bodies soothe the mind and filter pollutants, contributing to cleaner air and a healthier urban atmosphere. Integrating blue spaces into cities presents multiple obstacles, including space limitations, environmental harm, and financial restrictions. Urban planners are tasked with carefully balancing urban growth with the preservation of natural environments.

Moreover, pollution and lack of ecological care can deteriorate current blue spaces, reducing their value and potentially posing risks to local communities. To address these issues, urban planning must adopt innovative and sustainable strategies. One practical approach is to design blue spaces for multiple purposes, such as providing recreational areas, managing flooding, and supporting biodiversity. (Rush.)



Figure 8. The skyline and Lady Bird Lake in Austin, Texas (United States) (Michael Barera 2019)

2.3 Environmental awareness and Virtual Reality

Promoting environmental sustainability hinges on comprehensive education and public engagement strategies. Successful green infrastructure implementation requires citizens to understand its advantages and participate meaningfully in development processes. By leveraging targeted educational initiatives, informative communication campaigns, and inclusive public consultation mechanisms, communities can foster greater awareness and generate collective support for ecological solutions. Although investments in green infrastructure and modern cooling technologies may involve initial costs, they bring long-term savings. Lowering urban temperatures reduces the demand for cooling energy, resulting in

lower energy bills and fewer greenhouse gas emissions. Improving residents' health also means lower healthcare costs. (Katarzyna 2024.)

For people to invest in sustainable development, it is essential to awaken their empathy. Fortunately, modern technology enables us to experience realities beyond our usual perception. Virtual reality (VR) is a powerful tool that immerses users in digital environments, allowing them to witness potential future scenarios, including the consequences of climate change if no action is taken. Due to its immersive nature, VR has significant potential to foster empathy and raise awareness. Beyond entertainment and commercial applications, this technology can also be utilized for social, environmental, and educational purposes. Creating tools that align technological innovation with sustainability efforts can have a highly beneficial effect. (Mantu 2025.)

Exploring various applications of virtual reality can help illustrate its potential in addressing environmental concerns:

- **Stanford Ocean Acidification Experience:** Working with co-author Roy Pea, a Stanford professor and research director, Bailenson and his team introduced the Stanford Ocean Acidification Experience to over 270 participants, including high school and college students. In one experiment, seniors in a marine biology class at Sacred Heart Preparatory in California took on virtual identities as pink coral in a vibrant underwater reef. As the simulation progressed to the end of the century, the diverse marine life vanished, replaced by algae and acid-resistant fish, while the students' coral forms eventually disintegrated (Figure 9). The experience effectively immersed users, with researchers noting how students physically reacted by moving their heads and bodies, reinforcing their connection to the simulation and its environmental message. (Jordan 2018.)



Figure 9. Wearing a virtual reality headset, a researcher tries out the Stanford Ocean Acidification Experience, a new VR science education tool, with coral animation still in background (Stanford Virtual Human Interaction Lab 2016)

- **TheBlu: Immersing Users in the Beauty of Marine Life:** TheBlu is a highly immersive VR experience that allows users to explore the ocean's beauty and majesty by navigating different marine habitats and encountering extraordinary species. It offers a unique opportunity to witness the depths of the sea without requiring diving equipment or concerns about decompression sickness. Now available as an application with three distinct sections, TheBlu enables users to choose between experiencing a close encounter with a whale, observing a reef migration, or exploring the luminous abyss. Each setting unfolds over a set duration, during which marine creatures pass, encouraging users to remain attentive and fully appreciate their surroundings. While movement is limited, carefully observing the environment—looking behind rocks or beneath structures—reveals intricate details that enhance the experience and deepen the sense of admiration for the underwater world. (VrVoyaging 2022.)
- **Tree:** Tree is a virtual experience that allows users to embody a rainforest tree, with their arms as branches and their body as the trunk, witnessing its growth from a seedling to its complete form and ultimately experiencing its fate. Created in collaboration with directors Milica Zec and Winslow Porter, the project integrates precisely controlled physical elements such as vibration, heat, fans, and body haptics to enhance immersion. This fully immersive VR storytelling transforms the audience from

passive observers into active participants, enabling them to take on the identity of a towering tree within the Peruvian rainforest. (MITMediaLab 2017.)

Looking to the future, VR may also contribute to reducing global warming in other ways:

- **Environmental Protection:** VR can play a role in addressing climate change by enabling virtual simulations that support environmental protection and conservation work. With VR, park rangers and conservationists can observe and safeguard wildlife and natural areas remotely, avoiding direct interference with ecosystems. This approach helps preserve biodiversity while also cutting down on carbon emissions from travel to distant sites. (Trumper 2023.)
- **Sustainable Manufacturing:** Virtual reality technology can contribute to waste reduction in manufacturing by replacing the need for physical prototypes. Through virtual product simulations, companies can test and refine designs digitally, avoiding the production and disposal of physical models. This approach not only decreases waste but also lowers the consumption of raw materials and energy, promoting a more efficient and sustainable manufacturing process. (Trumper 2023.)
- **Reduced Travel Emissions:** Virtual reality can contribute to lowering carbon emissions by minimizing the necessity of physical travel. With VR, individuals can immerse themselves in real-world experiences and places without leaving their homes. This is especially relevant to sectors like tourism, where global travel significantly adds to carbon emissions. By offering virtual alternatives, VR allows people to explore destinations remotely, thereby reducing the environmental impact caused by transportation. (Trumper 2023.)
- **Paperless Workspaces:** Virtual reality can aid in cutting down paper waste in workplace settings. By enabling collaboration within virtual environments, VR removes the need for printed materials and in-person meetings. This not only decreases the use of paper but also lowers the carbon emissions linked to commuting for face-to-face gatherings. (Trumper 2023.)

In summary, VR technology holds great potential in tackling climate change and fostering sustainability. By raising awareness about its effects, encouraging sustainable solutions, and minimizing waste, VR can contribute positively to environmental efforts. As this technology continues to evolve, its impact on the environment is expected to grow even further. (Trumper 2023.)

3 Virtual reality

3.1 Definition

Sherman and Craig (2002) assert that, given the relatively recent emergence of virtual reality as a medium, its precise definition remains a subject of ongoing debate.

A potential definition of virtual reality (VR) is as follows: Virtual reality (VR) refers to a computer-generated, immersive three-dimensional environment with which users can interact. It is typically accessed through a computer capable of projecting 3D visuals onto standalone screens or wearable devices, such as head-mounted displays (HMDs). It is often supplemented by sensors that facilitate user identification and interaction. Virtual reality is generally classified into two main types: non-immersive and immersive. Non-immersive VR involves the use of multiple surrounding screens to display virtual content to the user. A common example would be flight or driving simulators, where the user remains seated while screens around them simulate a cockpit or vehicle environment, creating a semi-realistic experience without full immersion. On the other hand, immersive VR uses head-mounted displays to track the user's movements and display virtual content based on their position, offering a 360-degree view of the virtual world. This type of VR delivers the fully immersive experience most people associate with virtual reality and is one of its most appealing and widely promoted features. (Hamad & Jia 2022.)

Identifying the key elements of virtual reality can also be beneficial in establishing a clear definition:

- **Virtual World:** A virtual world can be defined as a collection of objects and the interactions that occur between them. Virtual reality involves experiencing this world through a system that facilitates both immersion and interaction. (Sherman & Craig 2002.)
- **Immersion:** Describing virtual reality as the experience of an alternate reality or point of view, this alternate reality can be identified as either a representation of an actual space or an entirely imaginary scenario. In traditional media, such as novels, books, and cinema, immersion into these alternative realities has always relied on the imagination of the audience. In contrast, virtual reality is distinguished by its ability to offer physical immersion, a feature that other forms of media cannot provide. (Sherman & Craig 2002.)
- **Sensory feedback:** VR systems deliver direct sensory feedback to users based on their physical position. While visual feedback is the most common, some systems

extend feedback to other senses, such as touch. To generate outputs corresponding to the user's position, the VR system must incorporate a tracking mechanism capable of monitoring the user's movements. (Sherman & Craig 2002.)

- **Interactivity:** Virtual reality cannot be regarded solely as visual immersion; creating authentic experiences heavily depends on the user's interaction with the medium. In part, VR distinguishes itself from other forms of media because it enables users to influence and interact with virtual environments actively. (Sherman & Craig 2002.)

Taking all these elements into account, Sherman and Craig (2002) define Virtual reality as a medium comprising interactive computer simulations that detect the participant's position and actions, providing feedback to one or more senses to evoke a sense of mental immersion or presence within the simulated environment (virtual world).

3.2 A brief history of Virtual Reality

A comprehensive understanding of virtual reality (VR) also requires exploring its historical development. Long before VR became a technological possibility, literature introduced concepts of immersion into alternative worlds. In 1935, the short story *Pygmalion's Spectacles* depicted a character who, using futuristic glasses, is transported to an idyllic simulated reality. Besides introducing the initial idea of "virtual reality," the story also draws on numerous literary and philosophical sources, such as 18th-century philosopher George Berkeley, the Greek myth of Pygmalion and Galatea, and Plato's Cave allegory from *The Republic*. This rich blend of philosophical thought and technological imagination anticipated the interests of many future VR creators, who would later explore similar themes. (Coursera Staff 2024.)

According to Dom Barnard (2024), in 1938 Sir Charles Wheatstone conducted a study demonstrating that the brain synthesizes a single image from the separate inputs of each eye. This discovery led Wheatstone to develop the first stereoscope, which used two mirrors on either side to create an illusion by reflecting two distinct images (Figure 10).

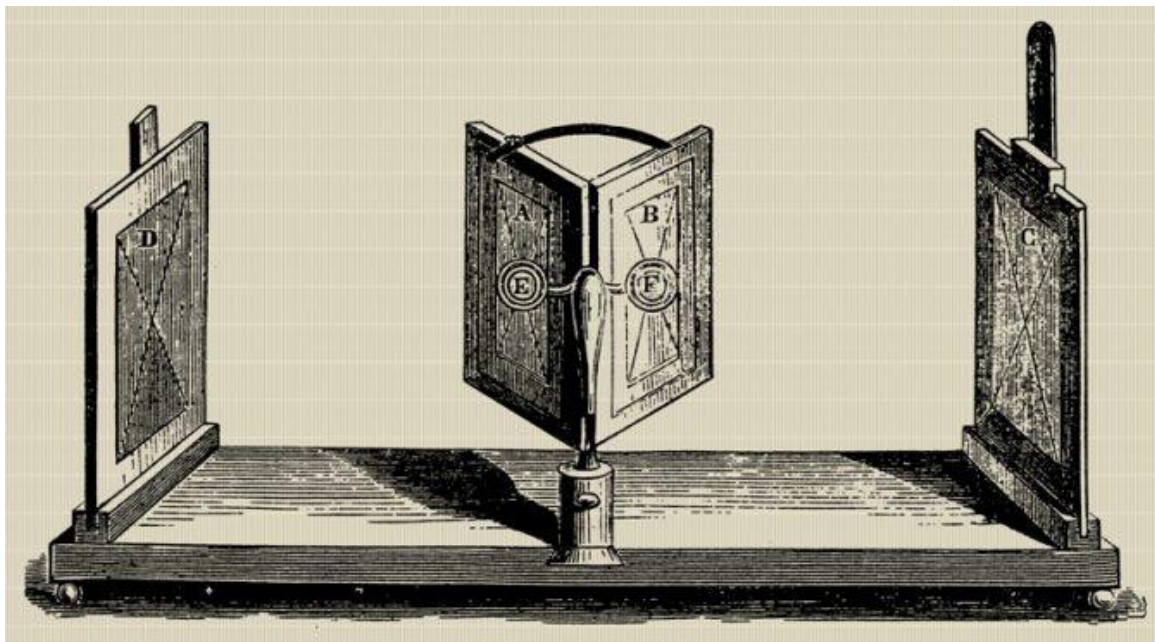


Figure 10. A brief history of photography by objects (Alan D 2019)

In 1968, a groundbreaking step forward in Virtual Reality technology was achieved by creating what is widely considered the first head-mounted display (HMD) specifically designed to enable immersive simulation experiences. This innovative device was developed by Ivan Sutherland and his team of students at Harvard University (Figure 11). Although the system was rudimentary by today's standards and required suspension from the ceiling to operate, it represented a pivotal moment in the evolution of virtual reality. The device laid a strong foundation for future advancements in the field, particularly in the areas of wireframe graphics and optical passthrough technology. (Watkins & Marenka 1994.)

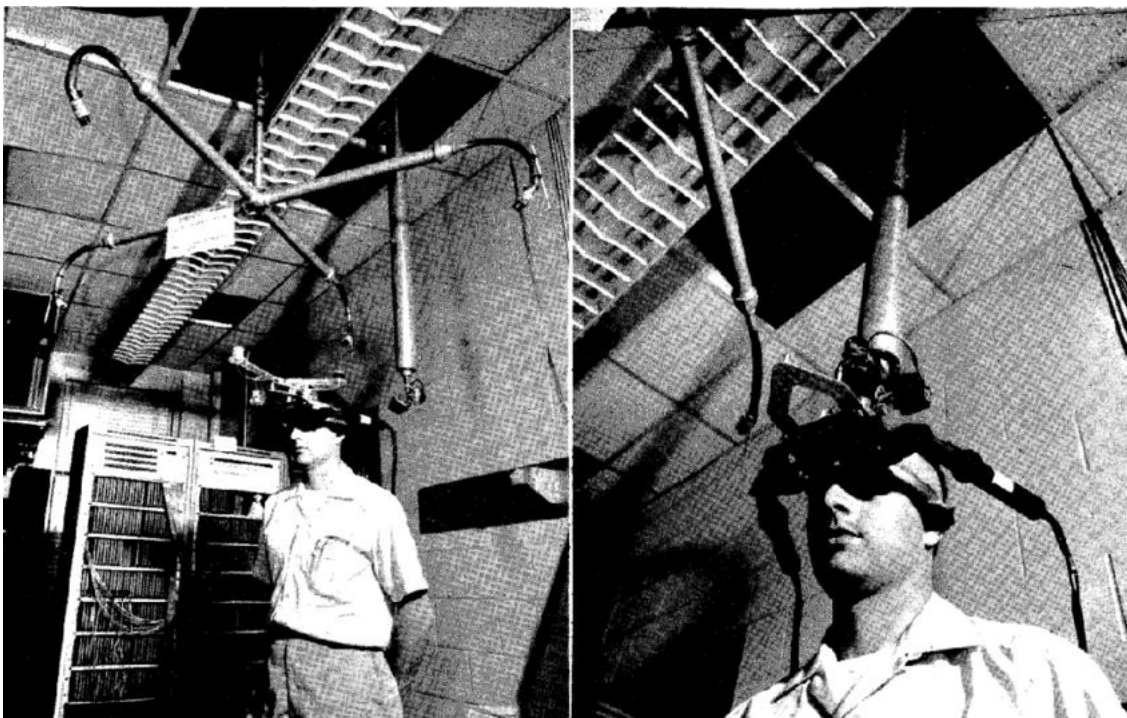


Figure 11. Sword of Damocles (Sutherland, 1968) (Sebastian Stadler 2021)

Other, less prominent projects may also be noted. Such as Videoplace, a system developed by Myron Krueger in the middle 1970's that allowed two users to interact from separate rooms via their projected images, representing an early stage of multi-user interaction within a virtual environment (Szilak 2014). Additionally, in 1979, the McDonnell-Douglas Corporation implemented virtual reality technology for military applications by developing a system that tracked the pilot's eye movements to align with computer-generated imagery (Barnard 2024). This decade marked a significant turning point in the perception of virtual reality by academic institutions and corporations, as it began to be regarded as a valuable tool for addressing critical applications rather than merely a novelty. (Coursera Staff 2024).

While the 1970s represented a pivotal period for virtual reality in academic and military applications, the 1980s marked VR's introduction into the business sector and the beginning of its commercialization (Coursera Staff 2024). In this era, it is essential to highlight VPL (Figure 12), a company founded by Jaron Lanier in 1982, recognized as a pioneer in the commercialization of virtual reality and credited with coining and popularizing the term "Virtual Reality". Even though the company went bankrupt in 1989, VPL marked a turning point in the history of VR. (Sorene 2014.) Some authors regard Lanier as the "father of virtual reality" (Leon 2022).



Figure 12. Future gazing: VPL Research demonstrated its EyePhone virtual reality system at the Texpo Telecommunications Show, in San Francisco, in 1989 (Simon Parkin 2014)

The 1990s, by contrast, marked the introduction of virtual reality into the world of video games. In 1991, the company *Virtuality* launched its first product, the *Virtuality 1000 series*. Although now outdated compared to modern products, it was the first VR system accessible to a broad audience and laid the foundation for emerging technologies in the field. In subsequent years, industry giants like Nintendo and Sega also entered the VR space, developing their own VR-based products. (McFerran 2024.)

Rogers (2019) explains that while virtual reality has undergone significant changes over the past few decades, it is in the 21st century that VR has genuinely transformed the world of entertainment. Today, VR technology is more accessible, lightweight, and faster than ever before.

In 2012, Palmer Luckey launched a Kickstarter campaign to fund the development of his prototype headset, the Rift (Figure 13). The campaign raised almost 2.5 million dollars, marking a significant shift from past consumer VR failures to the start of the modern VR revolution. By 2014, Oculus caught the attention of Facebook, which acquired the company, making Luckey extremely wealthy. This year also witnessed the launch of Google Cardboard, PSVR, and the Samsung Gear VR, thrusting virtual reality into the spotlight. Furthermore, Sony revealed plans to develop a VR add-on for the PS4, generating significant curiosity due to the console's relatively lower power compared to VR-capable computers. The

period between 2016 and 2017 saw a dramatic explosion in VR product launches. With the Rift and HTC Vive leading the way, a wave of VR products flooded the market, solidifying the technology's place in the mainstream, as evidenced by the growth of the HMD industry. (Virtual Reality Society 2017.)

In 2019, VR saw rapid progress as mixed reality and advanced technologies became key features of standalone headsets. The Oculus Quest was expected to offer tethering functionality, while smartphone VR projects began winding down. The price of VR headsets fell significantly, and the computer hardware needed for these devices became widely accessible. Exciting new technologies such as varifocal displays, wider fields of view, hand scanning, and eye tracking were on the way. Rumours also suggested that major companies like Apple were working on mixed reality projects, pointing to a future where VR and mixed reality would likely merge. (Virtual Reality Society 2017.)



Figure 13. A young Palmer Luckey (Blake Harris 2019)

Virtual reality (VR) has undergone a remarkable transformation, evolving from a niche concept to a mainstream technology that is now making a significant impact across multiple industries, including gaming, entertainment, healthcare, and education. Over the years, VR

has developed far beyond its initial experimental phase, thanks to continuous advancements in both hardware and software. These innovations have not only improved the quality of immersive experiences but have also enhanced the technology's usability, making it more accessible and appealing to a broader audience. The growth of VR has been further accelerated by the substantial investments from major technology companies, who recognize its vast potential in reshaping various sectors. As a result, VR is poised to expand even further, with new applications and breakthroughs on the horizon. In the next decade, VR is set to play an increasingly central role in transforming industries by providing innovative solutions that change how people work, learn, play, and interact. With its continued evolution, VR is positioned to be a powerful tool that will revolutionize the way we engage with the world around us. (Gupta et al. 2020.)

3.3 Virtual Reality and education

Virtual reality (VR) plays an increasingly significant role in education, as more learning institutions adopt this innovative technology. From kindergarteners who are part of a digitally native generation to university students gearing up for their careers, VR is revolutionizing educational approaches on a global scale. As VR technology continues to improve and become more accessible, its use in education is expected to increase. Educators and schools are already investigating its possibilities in fields such as medical training, cultural education, vocational training, and special education. VR has the capacity to transform education by making it more engaging, inclusive, and impactful. (HP Online Store 2024.)

Chandra (2024) emphasizes that VR has become a transformative educational tool, offering immersive experiences that significantly improve engagement, comprehension, and retention. By enabling students to immerse themselves in simulated environments, VR creates unique opportunities to make learning interactive and impactful.

Here are some key benefits of VR that stand out in education:

- Increased engagement and motivation: Studies indicate that students demonstrate increased motivation when engaging with virtual reality in specific contexts. According to an article in the *International Journal of Emerging Technologies in Learning*, medical students exhibited the highest motivation levels when learning through virtual reality, surpassing both video and text-based learning methods. (i3-Technologies 2023.)

- Simplification of abstract concepts: Many educational topics involve abstract ideas that are difficult to grasp through traditional methods. VR bridges this gap by providing visual and interactive representations, making complex concepts more tangible and accessible. (Chandra 2024.)
- Enhanced accessibility: VR technologies have the potential to address barriers in education, offering students with disabilities or those in remote locations access to enriched learning experiences that might otherwise be unavailable (Chandra 2024).

Surveys indicate that the majority of VR applications in education are focused on higher education and adult training. This is because VR provides access to a safe environment, allowing professionals to undergo proper training while avoiding the dangers of real-life scenarios. (Freina & Ott 2015.)

A notable example of this capability is the training of firefighters, who can practice their decision-making skills in a secure and controlled virtual space (Freina & Ott 2015). FLAIM Systems has developed a VR program for firefighter training (Figure 14). While these methods have successfully created a safer and more cost-effective training environment. The company's training solution is not intended to fully replace traditional firefighting training, but rather to enhance muscle memory through hands-on learning, better preparing personnel for high-stakes physical training. Key improvements include a highly sensitive heat suit, realistic audio experiences, immersive scenarios with actual equipment, and lifelike object interactions. Additionally, the platform's Team Training feature enables coordinated remote training for multiple users at once, offering a scalable, cloud-based solution that streamlines training across various teams and departments. (Sprigg 2023.)



Figure 14. 'Flaim Trainer' Uses Vive's Tracker For A Realistic Firefighting Experience (Jamie Feltham 2017)

The military industry was among the first to invest in VR, recognizing its potential early on, driven by the opportunity to reduce the costs of combat training. Therefore, using VR for military training and other state forces is not new. (Velichko 2018.)

The following examples represent just a small glimpse into the vast potential that virtual reality (VR) offers to the military sector:

- **Enhanced Ground Vehicle Simulators:** VR technology enables soldiers to train in various types of military vehicles with a level of immersion and realism that far surpasses traditional training tools like keyboards, mice, or even standard simulator wheels. It allows for the simulation of virtually any vehicle, from light reconnaissance units to advanced non-line-of-sight (NLOS) mortar carriers. VR applications can be tailored to replicate different roles within each vehicle, such as driver, gunner, or even hostage, capturing intricate details for a more accurate training experience. (Velichko 2018.)
- **Boot camp experience:** As video games became increasingly popular, the military began integrating gaming concepts into its training programs. Many modern soldiers

grew up playing games, making game-based training methods both familiar and effective. While early military games were played on regular consoles, they still helped future soldiers develop strategies and techniques applicable to real-life combat situations. (Velichko 2018.)

- VR in Combat Medic Training: Military medics often operate in high-pressure, dangerous environments where quick thinking and skill can mean the difference between life and death. Before the advent of VR, recreating such intense, war-like conditions for training purposes was nearly impossible. Today, virtual reality allows for the realistic simulation of combat zones, offering medics the opportunity to practice life-saving procedures in controlled, yet highly realistic scenarios. (Velichko 2018.)

Apex Officer (Figure 15) is a VR training simulator for police officers that can also be applied to the military, offering the ability to reproduce a wide range of scenarios (Rhodes 2020).



Figure 15. Samantha Terrazas during a virtual reality scenario using the Apex Officer training system (Maire O'Neill 2021)

It is also important to mention that not everything is positive when introducing VR into education. For instance, integrating VR into middle school education faces several challenges. Specifically, the rapid pace of technological advancements, limited student digital literacy, and insufficient teacher expertise pose significant obstacles. Still, these difficulties are not impossible to resolve. With the right guidance and resources, teachers can successfully integrate VR into their lessons and enhance both teaching and learning experiences. Research also indicates that the swift development of VR technology often outpaces the ability of educational systems to adapt. As a result, achieving seamless integration will take time, dedication, and thoughtful planning. It's important, therefore, to consider strategies for narrowing the gap between technological progress and educational readiness to better implement VR in schools. (Lin et al. 2024.)

While there are still important considerations and challenges unique to VR that must be addressed, such as technical requirements and equitable access, VR has matured to a point where it is not only theoretically useful for educational purposes but also has clear practical applications. Falling costs, mass-market availability, and improved immersive capabilities mean that VR is now feasible and practical for educational use. By overcoming these challenges, educators can fully harness the potential of VR to enhance learning experiences. (Lege & Bonner 2020.)

4 Case: Cool the City

4.1 Introduction

With the fundamental concepts of climate change affecting cities and virtual reality established, we can now transition from theory to application. This chapter presents a practical case that explores how interactive experiences can educate and engage users in addressing the challenges posed by extreme heat in urban environments.

Cool the City stems from the growing concern that modern cities are not well-prepared for heatwaves, a climate phenomenon that has become more frequent in recent years. The app takes its name from its core objective: to explore and promote practical ways to "cool the city" by implementing urban solutions that help reduce heat. The game's goal is to educate players on how small but meaningful changes can greatly enhance the well-being of citizens. At the same time, it seeks to raise awareness about the increasing challenges posed by climate change and how these extreme weather events can directly impact the lives of people living in urban areas.

To effectively convey this message, the game presents players with engaging yet straightforward tasks that reflect real-world solutions to heat mitigation. Disguised as a simple and relaxing experience, the gameplay allows for intuitive interaction while subtly encouraging players to consider the broader impact of their actions. What may seem like ordinary chores serve a deeper purpose, showing how small everyday actions can have a significant impact on regulating urban temperatures. By integrating these lessons naturally, the game remains both educational and entertaining.

Virtual reality (VR) serves as a powerful tool in this project, enhancing interactivity and reinforcing the idea that users have the agency to implement meaningful changes themselves. By immersing players in a simulated urban environment, VR enables them to directly experience the impact of their decisions, making the learning process more engaging and personal. The immersive nature of VR not only deepens players' understanding of the issue but also helps spark interest in the topic, especially among those who might be drawn in by the novelty and appeal of VR technology. Through interactive VR experiences, players can see firsthand how their choices shape the environment, encouraging reflection and real-world action.

4.2 Development tools and technologies

We can now turn to examining the technological foundation of the project. This section presents the key tools used in development, including Blender for 3D modeling, Unity as the

game engine, and Meta Quest 2 as the VR platform, emphasizing their roles in crafting an immersive and interactive experience. While these form the core of the project, several other tools were also employed for secondary but still important aspects. Figma was used to design and draw the UI elements, HumeAI provided AI-generated voices for narrating in-game dialogues, and Freesound was used to source copyright-free sound effects. These additional tools supported the development process, but will be mentioned only briefly moving forward, as they were not central to the technological structure of the application.

4.2.1 Unity

Unity was chosen as the development engine for this project due to its robust support for virtual reality, flexibility, and extensive community resources. As one of the leading platforms for VR development, Unity provides built-in tools and integrations that simplify the creation of immersive environments while offering compatibility with Meta Quest 2. Its user-friendly interface, along with a vast library of assets and plugins, accelerates development and allows for efficient prototyping.

Additionally, Unity's strong scripting capabilities with C# enable precise control over interactions, ensuring a smooth and engaging user experience. As an object-oriented language, C# integrates seamlessly with Unity, making it well-suited for managing game mechanics, physics, and player interactions. Its efficiency allows for real-time feedback and dynamic scenario adjustments, while its extensive documentation and strong community support streamline development and troubleshooting. By leveraging C#, the project benefits from a scalable and maintainable codebase, ensuring flexibility and long-term adaptability.

These features make it an ideal choice for developing an educational VR application that emphasizes interactivity and real-time decision-making.

4.2.2 Blender

Blender is a powerful open-source 3D modeling software used for creating and animating digital assets. It provides a wide range of tools for modeling, texturing, and rendering, making it a popular choice for game development. Its versatility, extensive features, and active community support make it an ideal tool for this project, making it a fitting choice for the development of the game's 3D assets.

The 3D models of the game have a cartoonish style to enhance visual appeal and improve user engagement (Figure 16). This artistic choice also serves a practical purpose, as Meta Quest 2 has hardware limitations that require models to have a low polygon count for optimal performance. By keeping the designs simple yet expressive, the game maintains a

balance between aesthetics and technical efficiency, ensuring a smooth VR experience. Moreover, this stylistic approach not only optimized performance but also streamlined the asset creation process. The reduced complexity of the models allowed for a more rapid development cycle, preventing unnecessary time investment in intricate detailing. This, in turn, enabled a stronger focus on refining gameplay mechanics and technical aspects.

In terms of color, light tones were used for the general scenario to convey a sense of emptiness and dryness, reinforcing the idea of heat and discomfort. In contrast, elements related to the missions, such as trees, fountains, and tools, were designed with bright and vibrant colors. This visual contrast helped distinguish essential interactive elements from the background and created a more substantial visual impact when the player introduced positive environmental changes.

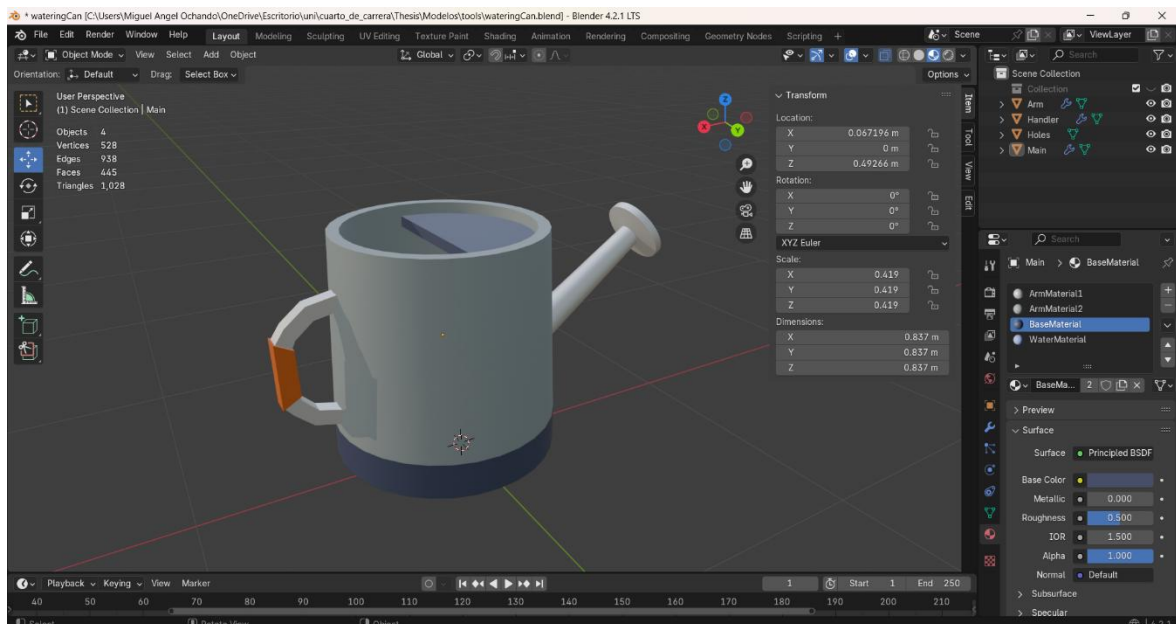


Figure 16. Low-poly watering can asset modelled in Blender

4.2.3 Meta Quest 2

Meta Quest 2 was selected as the VR platform for this project due to its balance of performance, accessibility, and ease of use. As a standalone headset, it eliminates the need for external sensors or wired connections, making it an ideal choice for an immersive and portable experience. Its built-in hand tracking enhances interactivity, allowing users to engage naturally with the virtual environment without requiring additional controllers.

Furthermore, Meta Quest 2 is optimized for Unity integration, ensuring smooth performance and efficient development. Given its affordability and widespread adoption, it provides an accessible entry point for users, making it a suitable platform for an educational VR experience.

4.3 Setting Up the Virtual Reality Environment

Once the concept for the project had been defined and the necessary tools selected, the next crucial step was to set up the development environment. This phase involved configuring the Unity project, selecting an appropriate version of the engine, and integrating the necessary packages to support VR functionality.

For the development of the app, Unity 2022.3.45f1 was selected, a long-term support (LTS) version, to ensure stability and compatibility throughout the project. This version provided essential improvements in performance and rendering, which are particularly important for VR applications that require high frame rates and low latency to maintain an immersive experience. Additionally, the VR packages utilized in this project were fully supported and optimized in this version of Unity.

The XR Interaction Toolkit and Oculus Integration package have been chosen for their ability to streamline the development of the VR environment, providing a robust foundation that simplifies the implementation of essential VR mechanics. These tools offer built-in support for common VR interactions, such as grabbing, pointing, and UI interaction, reducing considerably the need for extensive custom scripting. Additionally, they include locomotion features like teleportation and smooth movement, ensuring an intuitive and comfortable experience for the player. The availability of controller models and hand tracking further enhances immersion, allowing users to interact naturally within the virtual world. By leveraging these pre-made solutions, the development process becomes more efficient, allowing for greater focus on refining the core mechanics and overall experience of the game.

Once the development environment was properly configured, it was essential to establish intuitive and responsive movement mechanics to enhance player immersion. Given the importance of free movement in the game, a locomotion system was implemented by attaching a simple movement script to the XR Origin (Figure 17). This script enabled the player to navigate the virtual environment using the right controller's joystick. This functionality was supported by the XR Interaction Toolkit.

```
0 references
private void Update()
{
    Vector2 inputVector = moveAction.ReadValue<Vector2>();

    // Convert joystick input to world-space movement
    Vector3 moveDirection = new Vector3(inputVector.x, 0, inputVector.y);
    moveDirection = Camera.main.transform.TransformDirection(moveDirection);
    moveDirection.y = 0; // Keep movement flat

    characterController.Move(moveDirection * speed * Time.deltaTime);
}
```

Figure 17. Function showing the implemented player movement

In addition to movement, interaction with objects played a crucial role in the gameplay experience. XR Grab Interactable scripts were utilized to enable the player to grab objects within the environment. These scripts, provided by the XR Interaction Toolkit, facilitated object manipulation by allowing users to pick up, hold, and release items using their VR controllers. This implementation significantly reduced the need for custom scripting, as it leveraged built-in functionality optimized for virtual reality interactions.

Further refinement was introduced by enabling players to rotate and reposition held objects using the left controller's joystick. Although this functionality was already included in the interaction system provided by the downloaded library, it was modified to improve the user experience. Specifically, the input actions were customized so that object rotation could be performed exclusively with the left controller, allowing the right hand to remain free for navigation or other interactions. By adjusting the default input settings from the XR Interaction Toolkit, the interaction system was enhanced to provide players with greater control over objects, making interactions with the environment more intuitive and seamless, an essential aspect for ensuring a smooth and immersive gameplay experience.

Establishing a well-structured development environment was a fundamental step in ensuring a smooth and efficient workflow throughout the project. By carefully selecting the appropriate Unity version and integrating the necessary VR packages, many potential technical challenges were mitigated early on. This solid foundation not only facilitated the implementation of core mechanics but also streamlined the overall development process, making it easier to focus on expanding functionality and enhancing the usability of the application.

4.4 Main mechanics

The game incorporates three core mechanics, each representing a real-world action contributing to heat mitigation in urban environments: planting vegetation, unfolding awnings, and building fountains. These tasks were not designed to be highly realistic simulations but rather to be simple, entertaining, and accessible. The goal was to create gameplay that reflects impactful changes in the environment in a clear and satisfying way, without overwhelming the player with complexity. While inspired by real sustainable practices, these actions are intentionally stylized to keep the experience engaging and entertaining. This balance is crucial for an educational project, ensuring players stay motivated to explore and complete the game while absorbing its core message.

4.4.1 Planting mechanic

The task of planting a tree consists of three steps: digging a hole, planting a sapling, and watering it. To implement the first two steps, BoxColliders are used to detect collisions between the player's tools and the parcel assets. When a collision occurs, the parcel asset is replaced with a new one, visually reflecting the changes. First displaying a dug hole and then a planted sapling (Figure 18). This system ensures a smooth and interactive transformation of the environment as the player progresses.

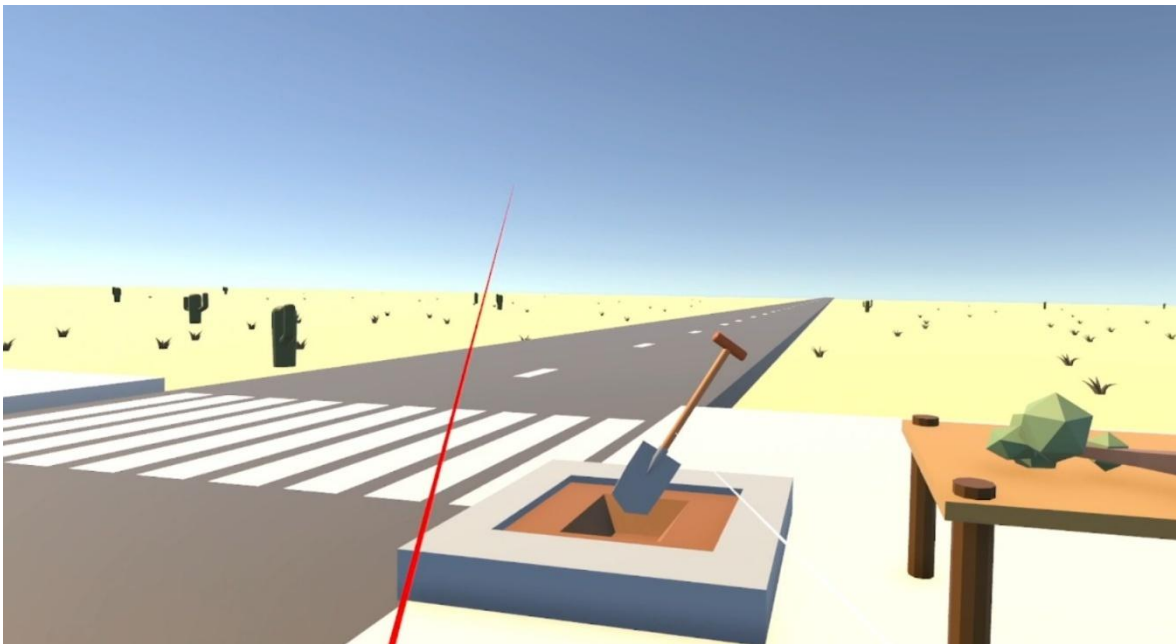


Figure 18. Digging Mechanic: transforming the ground for tree planting

For the watering process, a script on the watering can asset detects its inclination. When the can reaches a certain tilt, raycasts—invisible rays that detect objects in a specific direction—are projected toward the floor to determine where the water is falling. At the projected location, a new asset appears, representing the watered area. A particle system was also added to enhance realism to simulate water droplets pouring from the can. In Unity, a particle system is a visual effect used to create elements like smoke, fire, or rain by generating many small particles that move and fade over time. The script was modified so that the particles follow the direction of the raycasts, visually aligning the particle stream with the actual point of contact on the ground, making the water effect more convincing. The watered area contains a BoxCollider that, upon detecting a collision with the planted sapling, starts counting the duration of the interaction. If the watering can returns to an upright position, the script detects the change and stops pouring water, preventing further progress until the player tilts the can again. Once the required time has passed, a process similar to the previous steps is triggered, replacing the sapling with a fully grown tree, completing the task (Figure 19).

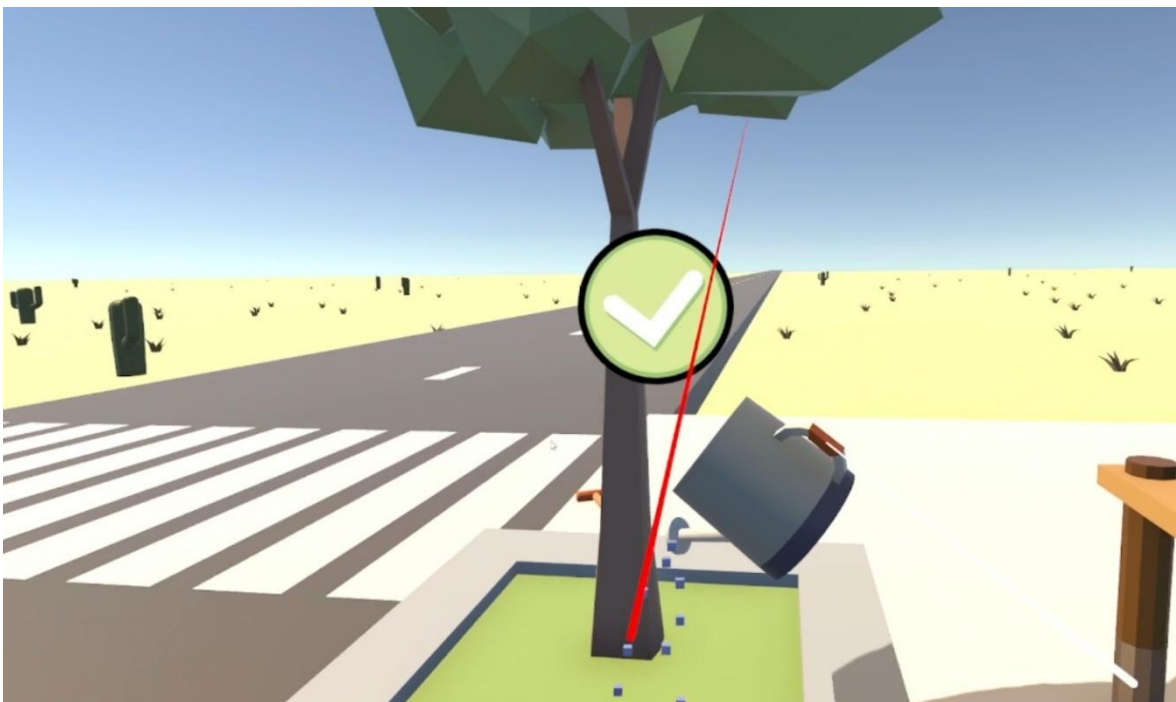


Figure 19. Fully grown tree after successful watering process

4.4.2 Awning mechanic

The awning task in the VR project consists of two main actions. First, the player must take an unattached crank and place it in the designated crank slot on the awning. Once the crank is correctly positioned, it becomes part of the awning mechanism. The second action involves rotating the crank to unfold the awning. This interaction is designed to simulate a realistic process, requiring the player to perform a circular motion with the controller to operate the crank.

The implementation of the crank placement follows a process similar to that of planting in the project. Initially, the crank is a grabbable item with a collider that detects when it is brought into contact with the designated awning slot. Upon successful placement, the unattached crank is removed, and a new, pre-positioned crank—previously hidden—becomes visible and interactive. Unlike the initial crank, this attached crank remains fixed in place. When the player interacts with it, they can rotate it through a natural circular motion, mimicking how a real crank would be used. This aspect of the implementation presented significant challenges, as multiple approaches led to issues such as incorrect rotational behavior or unrealistic movement patterns that did not align with the expected motion of a crank mechanism.

The code implementation of the crank mechanism relies on Unity's XR Interaction Toolkit, specifically extending the `XRBaseInteractable` class to create a responsive and immersive interaction. The `SteeringWheel` script is designed to handle the player's hand movements and translate them into a realistic rotational motion when interacting with the crank.

When the player grabs the crank, the script registers the event and calculates the current angle of the wheel relative to the player's position. As the player moves their hand in a circular motion, the script continuously updates the rotation based on the direction and angle of the input. This is achieved through a process that converts the player's hand position into a local coordinate system, determines the corresponding angular displacement, and applies the rotation to the crank's transform. A sensitivity factor is also included to adjust the responsiveness, particularly when multiple hands are interacting with the crank.

The `FindWheelAngle()` function (Figure 20), key element of the script, is responsible for calculating the total angular displacement of the crank based on the positions of all active interactors (hands). It loops through each interactor, converts its world position into local coordinates using `FindLocalPoint()`, and determines the corresponding angle using `ConvertToAngle()`. The result is then adjusted with a sensitivity factor from `FindRotationSensitivity()`, ensuring that the rotation responds naturally to the player's input.

```
3 references
private float FindWheelAngle()
{
    float totalAngle = 0;
    // Combine directions of current interactors
    foreach (IXRSelectInteractor interactor in interactorsSelecting)
    {
        Vector2 direction = FindLocalPoint(interactor.transform.position);
        totalAngle += ConvertToAngle(direction) * FindRotationSensitivity();
    }
    return totalAngle;
}
```

Figure 20. Calculating Crank Rotation Based on Player Input

One of the key challenges addressed by this implementation was ensuring that the rotation felt natural and intuitive. By refining the method for detecting hand positions and calculating the corresponding angle difference, the final implementation provides a smooth interaction that effectively generates a sense of realism, allowing the player's movements to closely mimic the real-world action of turning a crank.

However, the final version of the mechanic also presented some limitations. For instance, players could exploit the system by performing small back-and-forth movements instead of completing full circular rotations, which reduced the intended physicality of the interaction. Additionally, the rotation process was not always intuitive, as it required the controller to be positioned quite precisely for the system to register motion accurately. These issues occasionally disrupted immersion. Nonetheless, the crank mechanic still adds a unique layer of interactivity to the experience, and despite its imperfections, it successfully captures the player's attention and contributes meaningfully to the overall gameplay.

The rotation of the crank directly affects the unfolding of the awning. By rotating the crank, the code triggers a series of animations that simulate the awning expanding (Figure 21). This system is implemented using the Unity Animator System, which enables the developer to create and manage animations through a flexible state-based structure. The Unity Animator System allows animations to be represented as states such as “folded,” “unfolding,” or “unfolded” within an Animator Controller. These states are visually arranged and connected by transitions, which define how and when the animations switch from one to another. Transitions can be controlled by parameters such as booleans, triggers, floats, or integers, which are updated in real time through scripts or gameplay events. This system

supports advanced features like blending between animations and layering multiple animations simultaneously. In this case, when the crank is rotated, the system updates a parameter that causes a transition from the folded state to the unfolding animation, allowing the awning to expand smoothly. By using the Animator System, the developer can create complex animation behavior with high control and reactivity, ensuring that the unfolding of the awning feels both natural and responsive to the player's input.

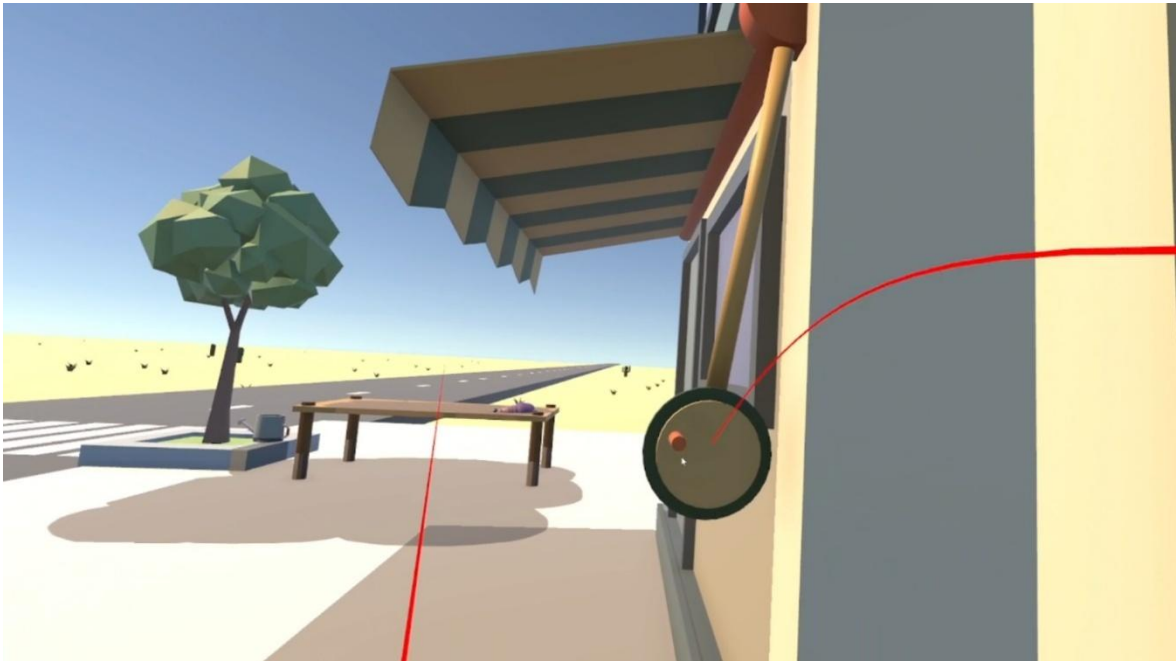


Figure 21. Player unfolding the awning while rotating the crank

This mechanic is implemented within the same script that handles the crank rotation. The script tracks the crank's rotation and measures the cumulative rotation time. Every two seconds of continuous rotation triggers a transition in the awning's animation state. When the player grabs and rotates the crank, the system calculates the angular difference from the last recorded rotation. If a significant change in angle is detected, the crank visually rotates, and a timer starts accumulating the duration of continuous rotation.

Overall, the crank mechanic offers players a different activity, adding variety to the gameplay. At the same time, it visually conveys an essential aspect of the game's educational purpose. The mechanic also results in a significant visual transformation in the scene, which is crucial for maintaining player interest and effectively communicating the impact of each action, aligning with the game's educational and awareness-driven goals.

4.4.3 Fountain mechanic

For the fountain mechanic, a system similar to the other mechanics in the game was used. The player must position a cube-shaped item into a designated area. By utilizing box colliders, after a certain amount of time, the fountain spawns in the area. This mechanic is implemented using a simple system that involves activating and deactivating objects, along with collision detection through the box colliders.

Once the fountain is spawned, the player can interact with it by pressing a button on their controllers while hovering over the fountain. This interaction triggers the activation of a particle system (Figure 22), simulating the flow of water from the fountain. Although this functionality is not required to complete the game, it adds an extra layer of interest and contributes to a more interactive and immersive experience for the player.

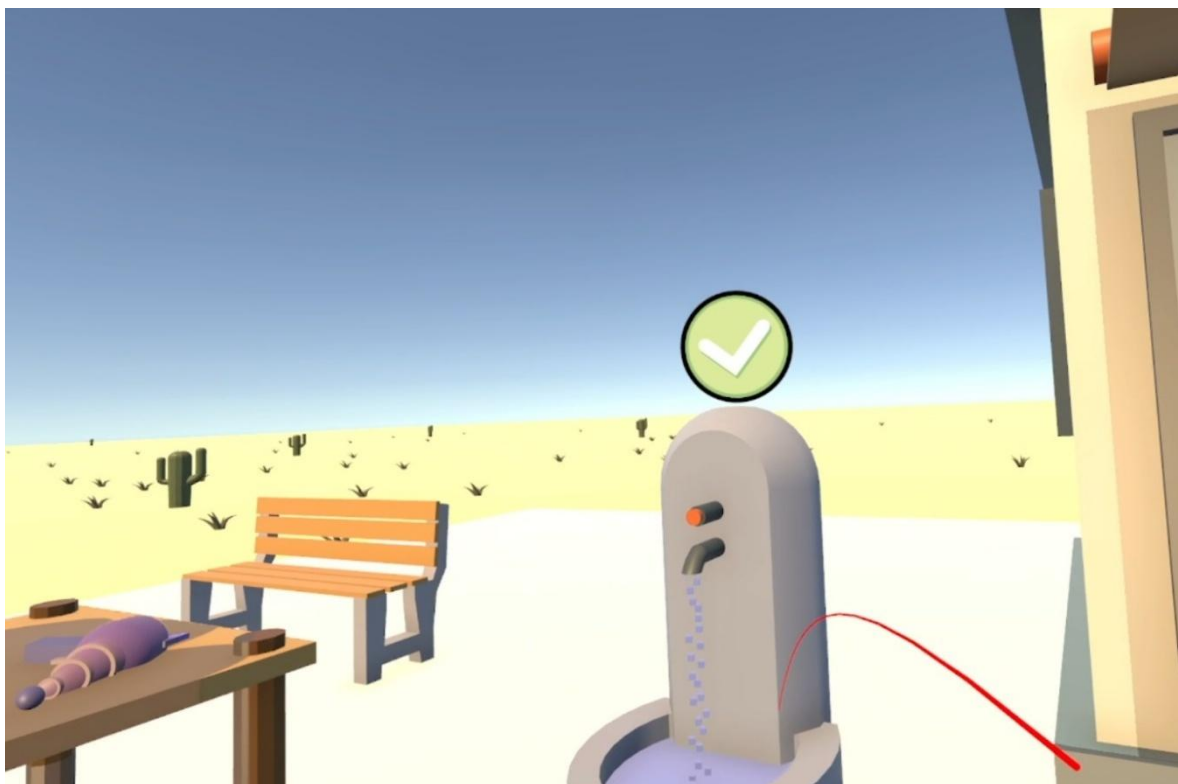


Figure 22. Working fountain with a particle system

This mechanic was designed to provide an entertaining task that engages the player, to illustrate the significance of fountains in a city, particularly during heatwaves. By allowing the player to interact with and activate the fountain, the mechanic highlights how such elements are not only aesthetically pleasing but also crucial for providing relief and comfort to citizens during high temperatures. Fountains and other water features help cool surrounding

areas by increasing humidity and reducing ambient temperatures through evaporative cooling. Water surfaces act as natural heat sinks, absorbing and dissipating heat, which can significantly alleviate the effects of the urban heat island phenomenon. In this way, the presence of fountains and similar structures contributes to more comfortable and liveable public spaces, especially in densely built areas. Through this interaction, players can better understand the importance of urban water features in mitigating the effects of heatwaves.

4.5 Shadows

Shadows were one of the most important aspects of this virtual reality project, as they played a crucial role in conveying the impact of the player's actions on the environment. The primary goal was to ensure that the player could see how the elements they introduced into the scene, such as trees, awnings, and buildings, generated shadows in real time. This visual feedback helped reinforce the idea that shading is a key factor in reducing heat in urban areas, especially during extreme weather conditions like heatwaves. By providing a clear and immediate visual representation of how different objects interact with sunlight, the project aimed to raise awareness about the importance of thoughtful urban design. It encouraged players to reflect on the environmental impact of their decisions, making the experience not only immersive but also educational. The accurate and dynamic rendering of shadows was more than a technical feature; it served as a powerful tool to communicate the broader message of sustainability and climate resilience.

For the implementation of shadows, a simple yet effective approach was chosen. Instead of relying on complex real-time shadow calculations, which could be performance-intensive, the project made use of Decal Projectors. Decal Projectors in Unity are components that allow textures to be projected onto surfaces in the scene, simulating effects such as dirt, stains, or, in this case, shadows. These projectors were pre-positioned in the environment and kept disabled by default, then dynamically activated when the corresponding elements appeared in the scene (Figure 23). This method was explicitly applied to elements like awnings and trees. A simple square-shaped decal was sufficient to simulate the shadow cast by the awning. In contrast, to create a more convincing shadow for the trees, a tree-like shape was designed using an online image editor and used as the texture for the decal, better matching the visual silhouette of the foliage.



Figure 23. Shadow cast by a planted tree

This implementation was managed by using tags and minor modifications in the code. Each environmental element was assigned a specific tag, allowing the system to identify when a new object was introduced into the scene. When an object appeared, its corresponding Decal Projector was enabled, creating the illusion of a dynamically changing environment. To enhance realism, a different shadow decal was prepared for each animation state of the awning, so that as the awning unfolded, the projected shadow changed accordingly.

This method effectively provided the player with immediate visual feedback on how their modifications influenced the shading of the city, reinforcing the educational aspect of the experience. Overall, the result was visually consistent with the game's aesthetic, maintaining the stylized look while conveying a sense of environmental transformation.

4.6 Spawning menu

Since the game takes place in a relatively large urban environment, it was essential to ensure that the player could easily access the necessary elements for completing tasks related to heat mitigation. To achieve this, an interactive menu system was implemented (Figure 24), allowing the player to spawn items as needed throughout the gameplay.

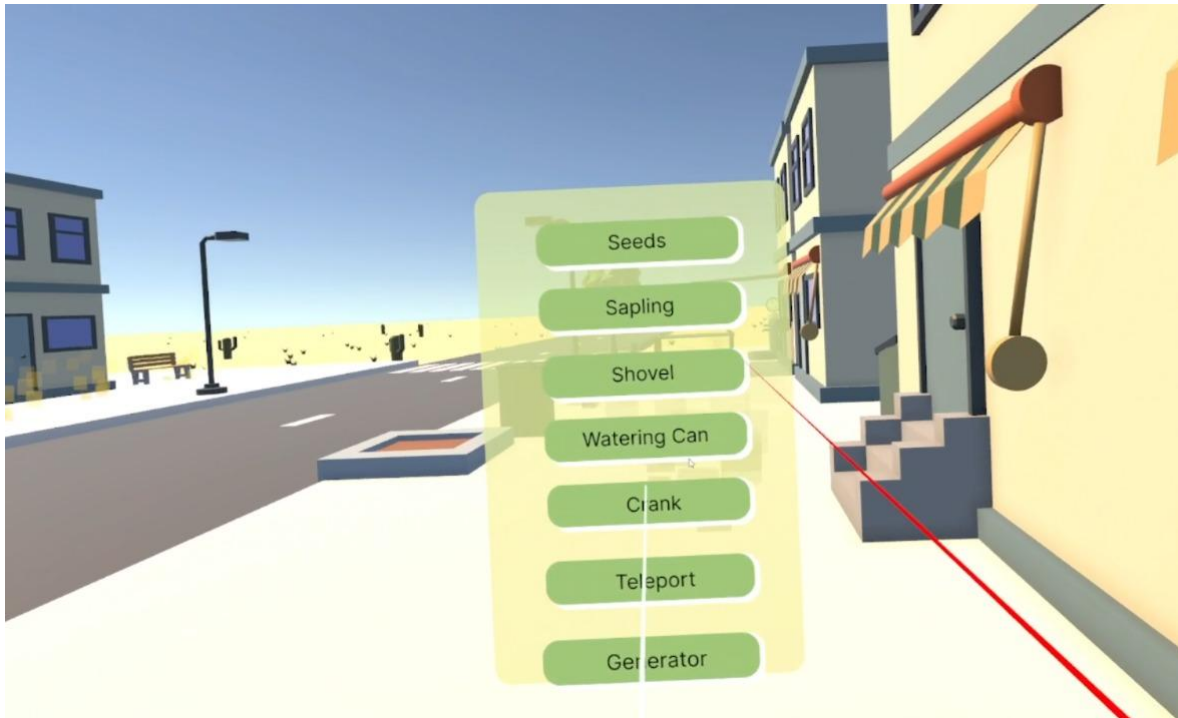


Figure 24. Spawning menu enhances player's accessibility to game items

The menu can be invoked at any time, ensuring accessibility regardless of the player's location in the scenario. Interaction with the menu is intuitive, as players can select different buttons to generate the required objects. The menu design dynamically follows the player's head movement. This ensures that the menu remains within the player's field of view, enhancing immersion and ease of use. Additionally, if the player moves while the menu is open, the menu follows them, preventing it from becoming unreachable in a large scene.

To further streamline gameplay, the system also manages the spawn point of the items. While the menu is open, the spawn point remains dynamically linked to the player's position. This prevents objects from spawning in unintended or unreachable locations as the player moves around the environment.

Another critical feature implemented is an item management system that controls the number of spawned objects. Every generated item is stored in a list, and when the maximum allowed number of objects is reached, the first spawned item is automatically removed. This prevents excessive object accumulation, which could impact performance and gameplay experience.

4.7 Teleport tool

The teleport mechanic is a crucial element of the game, as it allows the player to efficiently navigate a large urban environment while completing various tasks (Figure 25). While a

movement system was already implemented, teleportation proved to be a more convenient and accessible option for ensuring that the player could complete the missions without unnecessary delays or discomfort. This feature enhances the overall experience by providing a smooth and intuitive way to traverse the scenario.



Figure 25. The teleportation tool enables player movement within the scene

The teleportation system functions through a game tool designed specifically for movement. When the player aims this tool at the ground, a raycast (a technique that sends an invisible line from a point to detect objects along its path) is used to project a visual indicator showing the available teleportation area. If the player presses the trigger button while pointing at a valid location, they are instantly and comfortably transported to the designated position.

4.8 Mission system and scalable mechanics integration

To guide the player's progression and maintain engagement throughout the experience, the game implements a mission system. This system is designed around three core mechanics: planting trees, unfolding awnings, and constructing fountains. Each mission introduces the player to one of these mechanics and encourages interaction with the environment in a meaningful way. The missions are intentionally kept short to avoid repetitive gameplay,

which is especially important given the game's educational purpose. By keeping tasks concise and varied, the game aims to retain the player's attention and deliver its environmental message more effectively. After completing the main missions, the player is granted free time to explore the environment or engage in optional activities, reinforcing the core ideas at their own pace.

Initially, each interaction was hardcoded to occur only once, limiting the game's flexibility. However, in order to support multiple instances of each activity and create more dynamic missions, a scalable system was implemented. This system uses a simple identification method based on object names, assigning a unique ID to each interactive element in the scene. For example, if a sapling is planted in a parcel identified as "1", the system tracks this interaction and later spawns a corresponding tree with the same ID after a given period of time (Figure 26).

```

1 reference
private GameObject FindClosestInactivePlantedParcel(GameObject dugParcel)
{
    GameObject[] allObjects = Resources.FindObjectsOfTypeAll<GameObject>(); // Finds ALL objects, including inactive ones
    GameObject closestParcel = null;
    float minDistance = Mathf.Infinity;

    foreach (GameObject obj in allObjects)
    {
        if (obj.CompareTag("PlantedParcel") && !obj.activeInHierarchy) // Ensure it's tagged and inactive
        {
            float distance = Vector3.Distance(obj.transform.position, dugParcel.transform.position);
            if (distance < minDistance)
            {
                minDistance = distance;
                closestParcel = obj;
            }
        }
    }

    return closestParcel;
}

```

Figure 26. Function that finds the object identification

Additionally, Unity's tagging system was used to handle specific interactions, particularly when objects like tools needed to be recognized by the game. For instance, identifying a collision between a shovel and a dirt patch relied on the "Shovel" tag to ensure proper behavior.

With this scalable structure in place, the mission system was developed to track and respond to gameplay progress. Each mechanic was equipped with scripts that included functions triggered by the successful completion of tasks, such as building a fountain, and functions for verifying whether a task had already been completed. The mission manager then

coordinates the gameplay flow by calling these functions at the appropriate times within each mechanic's script. This modular approach ensures that the system remains extensible and adaptable, allowing the reuse of mechanics across the game.

In the final stages of development, the decision was made to design each mission around a single task. This approach aimed to keep the experience as engaging as possible, avoiding the risk of overwhelming or tedious the player with overly complex objectives. By simplifying the structure, the game allowed for a more open-ended experience in its final phase, giving players the freedom to explore and complete any task they wished after the tutorial. This design choice supported the delivery of the game's core message in a concise yet impactful way, ensuring that the brief experience remained appealing while effectively reinforcing the educational goals.

4.9 Dialogue system and user feedback

The dialogue system played a fundamental role in the development of the game, as it was key to fulfilling its educational purpose. Since the game is meant to raise awareness and deliver a meaningful message about climate change and urban heat mitigation, it was essential to provide the player with guided communication. Dialogues serve a dual purpose: they not only convey educational content but also function as a tutorial by explaining how the game's mechanics work.

Dialogues appear at the starting point of the experience, where the player begins the game. After completing each mission, the player must return to this initial location and press a button to trigger the next set of dialogues (Figure 27). This structure creates a rhythm in which players receive context and guidance before proceeding to the next objective. Additionally, after each mission, players receive a brief explanation of how the task they have just completed contributes to mitigating heat in the urban environment, reinforcing the educational purpose of the experience.



Figure 27. Skip button allows the player to navigate the dialogues

To ensure accessibility, the dialogues were designed to be concise, clear, and written in a neutral, standard tone. This helps make the content understandable for a wide audience, avoiding complex language or lengthy explanations. The aim was to inform the player without overwhelming them, maintaining engagement while progressively sharing insights about how the in-game actions relate to real-world improvements in city environments.

From a technical standpoint, the system was implemented through a dedicated script that manages the display of dialogues. This script is triggered at the beginning of the experience and again whenever the player interacts with the "Next Mission" button. Additionally, a skip button was included to let users control the pace at which they read the dialogues. This decision, as opposed to auto-progressing text, enhances user comfort and respects individual reading speeds, contributing to a smoother and more personalized gameplay experience.

After successfully implementing the dialogue system, attention turned to enhancing the player's experience with another feedback mechanism. This new system was designed to provide immediate feedback to the player upon completing missions or tasks, such as unfolding an awning. The goal was to add a layer of interactivity and acknowledgment, as the game was feeling a bit flat without any feedback.

An initial approach to the feedback system involved integrating it into the mission management script, which calculated the closest predefined point to the player's position to display a message indicating task completion. However, this method was later discarded in favor of a simpler and more efficient solution. In the final version, a set of icons was manually placed at the locations where each task takes place. These icons were initially hidden and were activated through a script when the corresponding mission was completed, using tags to identify the relevant elements. Rather than displaying full messages, the system now simply shows a visual icon to indicate that a task has been successfully completed (Figure 28).

The feedback icons were designed to rotate along the y-axis to ensure clear visibility in VR, always facing the player automatically. This simple adjustment helps maintain readability regardless of the player's position or orientation in the scene, making it easier to recognize completed tasks.

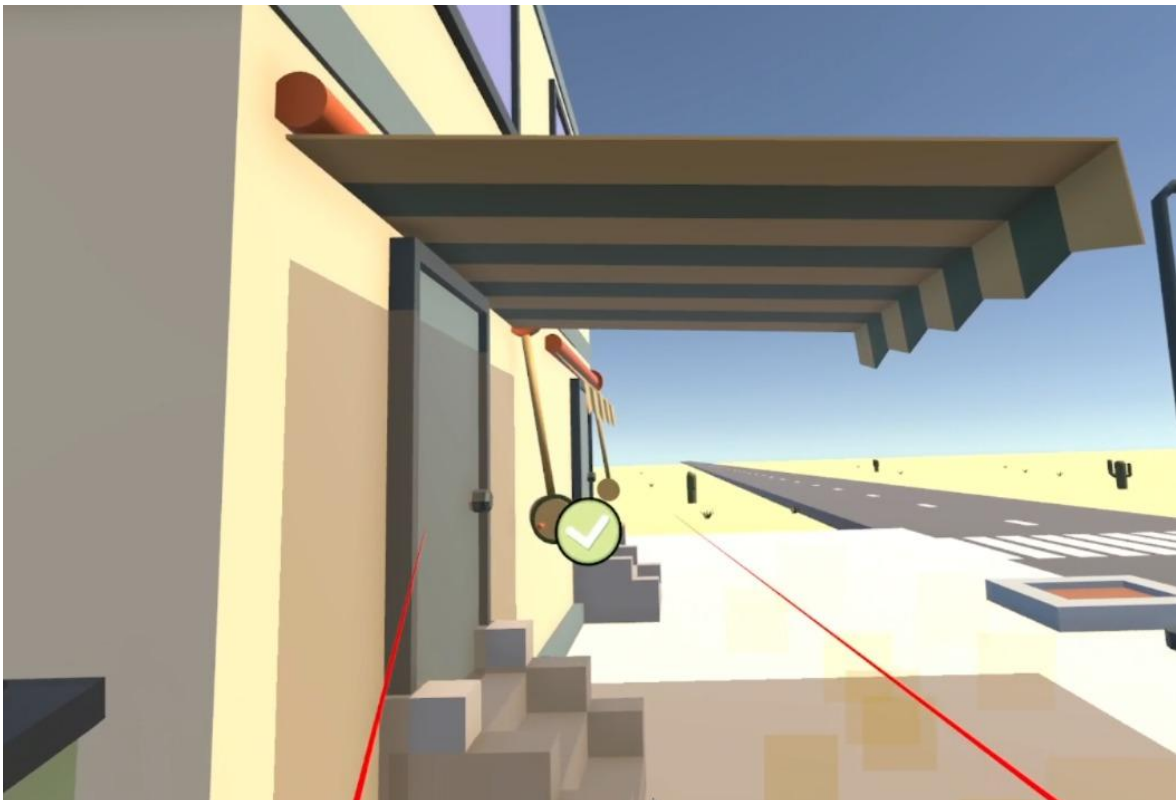


Figure 28. Feedback displayed each time a task is completed

The icons remain active until the player progresses to the next mission, allowing for an easy and continuous visual reference of which tasks have already been completed. This approach not only helps the player keep track of their progress but also contributes to the overall visual appeal and style of the game.

During the final stages of development, the game's user interface was redesigned to create a more visually appealing and cohesive experience. Figma was the chosen tool for this process, as it allowed for the efficient creation of clean and attractive icons. The new UI style was intentionally kept simple to align with the game's educational and user-friendly approach (Figure 29). A green pastel color palette was used throughout, reinforcing the environmental theme and message of the game. With this refreshed UI design and the inclusion of well-structured dialogues, the final product offered a significantly improved user experience—one that was not only more engaging but also more effective in delivering the game's core message.



Figure 29. Newly designed user interface elements in Figma

In the game's final version, AI-generated voices were incorporated to narrate the dialogues, adding a layer of engagement and polish to the user experience. These voices were created using Hume AI, an online tool that converts text into speech with various voice options. A neutral-sounding male voice was selected to maintain a clear and accessible tone suitable for all users. The primary goal of this addition was to enrich the educational aspect of the

game, which previously felt somewhat flat without audio support. By giving voice to the dialogues, the experience became more dynamic and immersive, helping to capture the player's attention better and convey the game's environmental messages more compellingly.

4.10 Sound implementation in the game

Incorporating sound into the virtual reality (VR) game was a crucial element for enhancing the overall experience. Sounds play a key role in creating immersion and realism, preventing the game from feeling flat and adding depth to the player's interaction with the environment. They enrich the gameplay by providing auditory feedback that complements the visual elements. The game's sounds were sourced from Freesound, a website offering royalty-free audio files. One of the challenges encountered during this process was the need to ensure that every sound used had a Creative Commons 0 (CC0) license, meaning they were free to use without any copyright restrictions. This requirement extended the search time, as not all suitable sounds were available under this license. Some of the selected sounds also required editing before integration into the game. For this task, Audacity, a free audio editing tool, was used. It allowed for cutting the sounds to the necessary lengths and adjusting their volume levels to ensure the soundscapes were balanced and optimized for the user experience.

A wide variety of sounds were added, including those for mission completion (such as popping sounds) and interactive elements like the digging sound when the shovel collides with the ground. Additional sound effects were implemented to accompany key interactions throughout the experience, such as the sound of water flowing from the watering can and the fountain, the subtle plop of seeds dropping from the seed box, and the distinct activation sound of the teleportation tool. These audio elements were carefully selected to align with the corresponding actions.

Technically, the implementation of these sounds was relatively straightforward, as most were tied to specific in-game events and triggered through simple code modifications. However, some sounds required slightly more complex handling depending on the type of interaction. For example, one-time actions like planting saplings or activating the teleport tool only needed a short sound clip played once at the moment of interaction. In contrast, other actions demanded more dynamic sound control. A clear case is the crank rotation, which required a looping sound that plays continuously while the player is turning the crank and stops precisely when the action ends. This was implemented by using the looping feature

in the audio system and monitoring the interaction state to control playback accurately (Figure 30). This combination of different sound triggers helped ensure that each interaction felt natural and responsive.

```

1 reference
private void RotateWheel()
{
    float currentAngle = FindWheelAngle();
    float angleDifference = Mathf.DeltaAngle(lastAngle, currentAngle);

    if (Mathf.Abs(angleDifference) > 1f) // Ignore small jitter
    {
        wheelTransform.Rotate(Vector3.forward, -angleDifference);
        rotationTime += Time.deltaTime;

        // Play sound while rotating
        if (!audioSource.isPlaying) // Start the sound if it's not already playing
        {
            audioSource.PlayOneShot(rotatingSound);
        }
    }
}

```

Figure 30. Triggering sound function while the crank is being rotated

In summary, sound design significantly contributed to the immersive nature of the game, and with the proper technical implementation, it added an engaging layer of interactivity and realism for the player.

4.11 Simulating heat effects in the virtual environment

One of the final features added to the game was the implementation of special effects designed to simulate the extreme heat of a summer environment. Given the primary objective of the game, which aims to immerse the player in a scenario focused on heat and its impact, this feature plays a crucial role in enhancing the player's engagement with the mission and overall objectives. Achieving an atmosphere that conveys the sensation of intense heat without the physical experience of it was a complex challenge, requiring the integration of several systems that effectively evoke the feeling of summer and sweltering heat.

The first and most straightforward system involved altering the lighting of the scene. By adjusting the intensity and warmth of the main light source, a harsh, sun-baked effect was achieved. This created the sensation of an unforgiving sun beating down on the environment. In addition to lighting, a particle system was employed to simulate sun rays. These particles were positioned above the player's head and spread across the sky (Figure 31).

To enhance realism, the particles were extended and given a bright, transparent appearance. However, a challenge arose due to the static nature of the sun in the scene—if the player moved, the sun rays appeared out of place. To address this, a script was implemented to synchronize the particle movement with the player's position, ensuring the rays always remained aligned with the sun's direction.

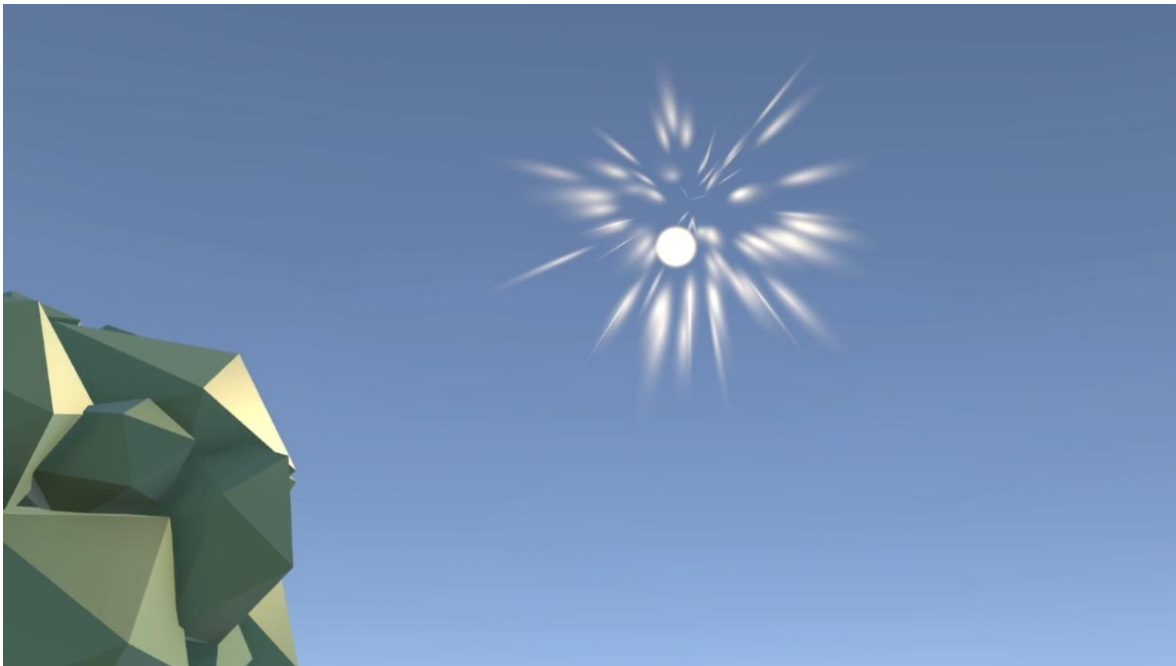


Figure 31. Simulating sun rays using a particle system

The second system introduced was the use of sound to complement the visual effects and heighten immersion. Ambient sounds are often a critical component in creating a believable atmosphere in games. In this case, two types of sounds were utilized: the hum of cicadas on a hot afternoon and the soft sound of a breeze. These sounds were played in the background at a low volume, ensuring they did not overwhelm the player but remained present enough to reinforce the feeling of heat throughout the experience. Similar to the previous sound system, these ambient noises looped during the entire gameplay, with intermittent pauses to avoid becoming repetitive or annoying.

Another significant element in reinforcing the hot environment was the careful selection and placement of assets within the game. Cactus and dried desert plant models were scattered throughout the terrain, especially outside the city, to visually emphasize the arid, desert-like atmosphere (Figure 32). The inclusion of such assets contributes to the overall impression of heat, helping to ground the player in the virtual world.

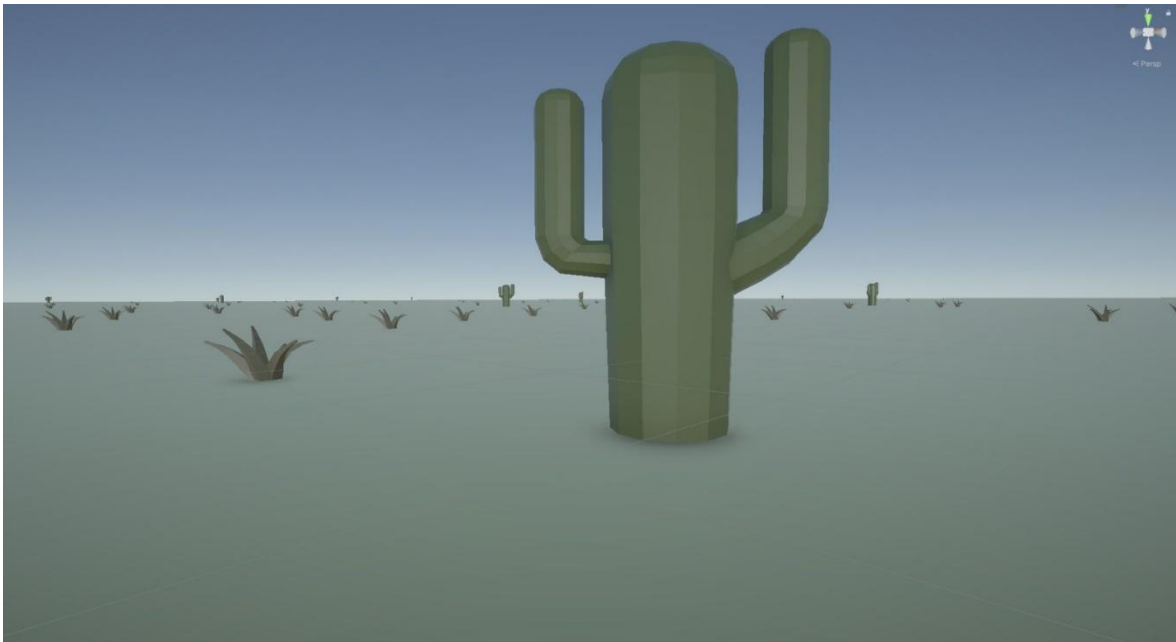


Figure 32. Cactus and dried plants used to represent a desert environment

Finally, particle systems were again employed, this time to simulate heat-induced vapor rising from the ground. Simple square-shaped particles were chosen to minimize scene complexity while still conveying the desired effect. These particles were given a yellowish tone to evoke the sandy, sunbaked environment. To add an interactive layer to this effect, the code was adjusted so that the vapor would disappear if a shadow was cast over it. This added a layer of interactivity, allowing the player's actions to visibly alter the environment—an important feature that aligns with the game's objective of engaging the player in meaningful ways.

4.12 Main menu and replay features

One of the final features developed for the game was the main menu. This was implemented in a separate Unity scene designed to resemble a bus station in the desert (Figure 33). The setting was intentionally chosen to introduce the player to the game's environmental context: an arid, hot, and desolate area, reflecting the consequences of climate change and the absence of green infrastructure. This bleak atmosphere aimed to emphasize the importance of the changes the player would later be able to make in the main scene. In this menu scene, player movement is disabled, and the only available interaction is pressing the "Play" button to begin the experience.

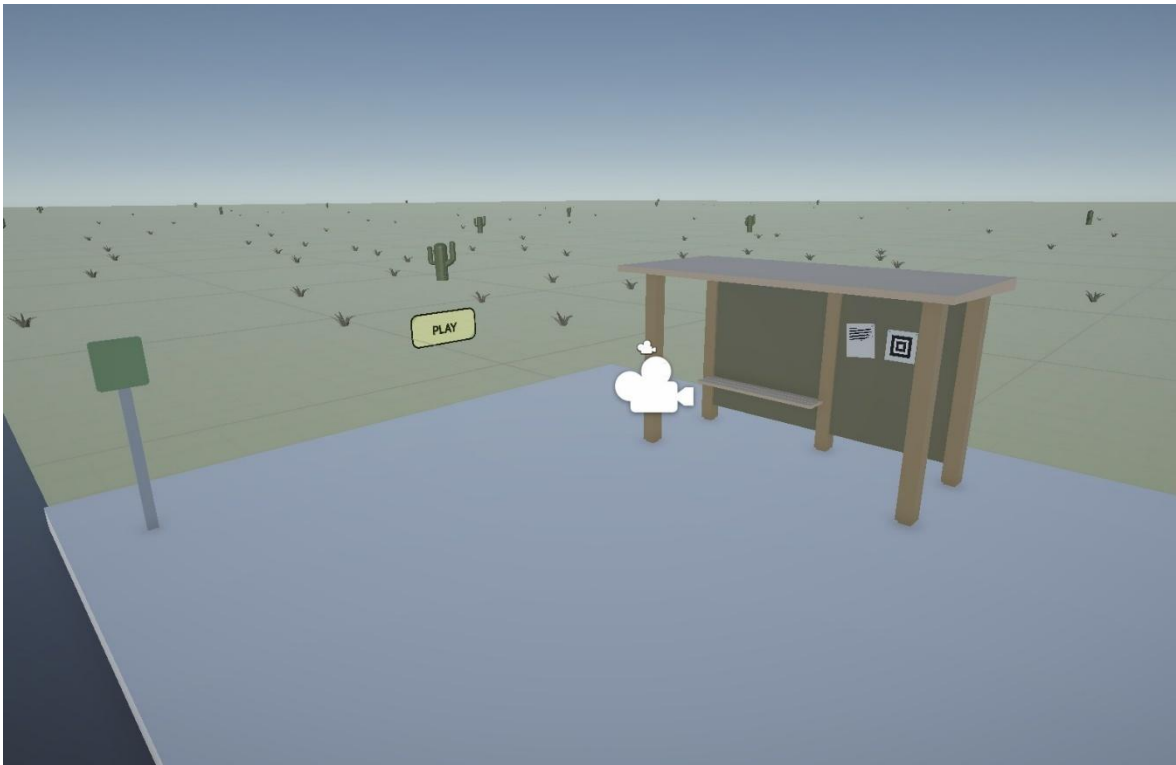


Figure 33. Main menu scene

To enhance the user experience, a transition effect was implemented between the main menu and the main game scene. This transition was achieved using Canvas, which in Unity is a component that allows UI elements (such as images, text, or buttons) to be rendered in screen space or world space. In this case, the canvas was attached to the player's camera, essentially the player's point of view, ensuring that the transition effect always appeared directly in front of the user. A black square was created within the canvas and animated to move from right to left when the "Play" button in the main menu was pressed. Upon entering the next scene, a similar animation played, but with the square moving from left to right. This simple yet visually effective technique helped create a smooth and polished transition between scenes.

An additional button was added at the end of the game, allowing the player to return to the main menu. This button was accompanied by a brief message explaining that, once the player feels they have completed the experience, they can return to the main menu and replay the game if desired. These additions helped tie the whole experience together, making the game feel more complete and giving it a more polished and professional look.

5 Summary

The result of the thesis presents a virtual reality game designed to educate and raise awareness about the crucial issue of heat mitigation in urban environments. The game offers a short and straightforward experience where players complete missions based on real-life strategies to combat extreme heat in cities. These tasks include planting trees and vegetation, unfolding awnings that provide shade, and building fountains. It strikes a balance between learning and enjoyment, delivering its message in a way that is accessible and avoids becoming overwhelming or tedious. By leveraging virtual reality, the project introduces a fresh and engaging approach to a pressing issue, potentially reaching audiences who might not have shown interest otherwise.

The theoretical part of the thesis serves to introduce the concept of virtual reality and highlight its potential, while also emphasizing the seriousness of climate change and how VR can contribute to addressing it. Understanding how modern cities are currently tackling heat-related challenges was crucial for designing the game's missions, as this information directly inspired the in-game tasks. Researching existing VR applications used for education and communication played an important role, especially those specifically focused on climate change. These examples offered valuable insights and helped shape a more effective and meaningful way to deliver the game's message.

In the practical part of the thesis, the result—Cool the City—offers a short yet meaningful experience that successfully provides a smooth and thoughtful user journey. The game effectively captures the player's attention and raises awareness about a relevant global issue. This section of the thesis delves into the key design and development decisions made to convey the intended message better. While the game may appear lighthearted or simple at first glance, the underlying missions carry a deeper meaning. Beneath the surface of planting trees or activating fountains lies a reminder that even small actions can contribute to solving larger problems. The overall tone of the game is optimistic, suggesting that anyone can begin positively impacting issues that might seem impossible to solve at first or that people don't even stop and think about.

As a final thought, the entire process of game development and thesis writing can be compared to the journey of the game's concept itself. There was little optimism when the project began, as there was limited experience in the field and expectations were not particularly high. Despite this, the project slowly progressed through dedication and consistent effort, leading to a successful result, although not being perfect. What initially seemed like an im-

possible challenge eventually became achievable with the right amount of work. This process mirrors the spirit of Cool the City itself: by taking small, consistent actions, something that may seem unattainable can eventually be accomplished.

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