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BACHELOR THESIS

Virtual dental patient experience for children with autism spectrum disorder

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Anotace

Děti s poruchou autistického spektra bývají mnohými zubními lékaři považovány za neošetřitelné pacienty. Komplikace spojené s poruchou zasahují i do dalších lékařských oborů a oblastí života. Tato bakalářská práce popisuje jak může virtuální realita pomoci se zvládáním těchto situací. Práce dále prezentuje vývoj prostředí zubní ordinace ve virtuální realitě v Unity pro HTC Vive Pro. Virtuální realita uživateli umožňuje trénink čekání s vizualizací času v čekárně, setkání s lékařkou a sestrou na recepci, postup do zubní ordinace nebo odchod, prohlídku zubní ordinace a detailní seznámení s ní. V zubní ordinaci vystupují lékařka a sestra, a uživatel má možnost se kdykoliv vrátit na recepci nebo odejít úplně.

Synopsis

Children with autism spectrum disorder are often considered by many dentists as untreatable patients. Complications associated with the disorder affect other medical fields and parts of life. This bachelor thesis describes how virtual reality can help manage such situations. Furthermore, the thesis presents the development of a dental office environment in virtual reality in Unity for the HTC Vive Pro. Virtual reality allows the user to train for the waiting process with a visualization of time in the waiting room, meet the dentist and nurse at the reception, proceed into the dental office or leave, explore the dental office, and familiarize themselves with it in detail. The dentist and nurse are present in the dental office, and the user has the option to return to the reception at any time or leave.

Klíčová slova: virtuální realita; porucha autistického spektra; VR; PAS, Unity

Keywords: virtual reality; autism spectrum disorder; VR; ASD, Unity

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By submitting this text its author declares that he/she has completed this thesis including its appendices on his/her own and used solely the sources cited in the text and included in the bibliography list.

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1 Introduction

Children with autism spectrum disorder (ASD) are often considered by many dentists as untreatable and uncooperative patients. Consequently, they are frequently treated only under general anesthesia and in severe situations. There are initiatives aimed at improving this situation, such as those undertaken by JAN z.s. [1] in the Olomouc Region. The most effective therapeutic technique to manage such cases is Exposure Therapy [2]. Virtual reality (VR) is a promising tool in Virtual Reality Exposure Therapy.

The first chapter introduces my motivation, the essential requirements for the thesis and provides background information on ASD and JAN z.s. It also discusses the barriers to dental care access for children with ASD, applications of VR in related areas, an example of VR-based ASD training system, and potential future explorations.

1.1 Motivation

Since 2019, I have worked as a dental assistant, which has given me a deeper understanding of the dental environment and its challenges. I am aware of the general barriers to dental care access and can empathize with the situation from a healthcare professional's perspective. Managing fear-related behaviors in dental treatments is challenging, even for children without ASD. In my opinion, every child deserves proper dental care and should be treated with respect.

There are promising applications of VR in healthcare and dentistry. For instance, "A Framework to Enhance the Experience of CBCT Data in Real-Time Using Immersive Virtual Reality: Impacting Dental Pre-Surgical Planning" [3] was developed to help dental surgeons enhance the understanding of complex dental structures and pre-operative planning in dentistry. Other applications like Keppy [4] help dentists effectively distract patients, and Virteasy Dental [5] is a simulator developed for dental students. "A Virtual Dental Office Experience for Children With ASD" [6] is an ongoing study evaluating the effectiveness of VR (360° video) for reducing dental anxiety in children with ASD.

Also, applications of VR in dental phobia and ASD therapy have shown benefits for individuals with ASD. [2], [7] The dental environment often evokes feelings of pain, fear, and anxiety, but in 2024, these experiences can be better managed.

Creating a dental office environment in VR allows me to use my experience as a dental assistant, learn about game development in Unity [8] and consult with experts from JAN z.s. to better understand the needs of children with ASD.

1.2 Autism spectrum disorder (ASD) and JAN z.s.

ASD is a neurodevelopmental disorder defined by deficits in social communication and the existence of restricted interests and repetitive behaviors. [9]
The transition to the new diagnostic manual (DSM-5) will likely impact prevalence, which was at 1 in 59 children in the US in 2020 [9] and approximately 1 in 100 children worldwide in 2022 [10]. There are no accurate statistics in Czech Republic. ASD is a neurobiological disorder influenced by genetic and environmental factors. [9] In DSM-5, the concept of a "spectrum" ASD diagnosis was created, combining the DSM-IV's separate pervasive developmental disorder (PDD) diagnoses like autistic disorder, Asperger's disorder and more into one.
A separate social (pragmatic) communication disorder (SPCD) was established for those who have disabilities in social communication, but repetitive, restricted behaviors are absent. Additionally, severity level descriptors were added to better categorize the level of support needed by an individual with ASD. ASD occurs in all racial, ethnic, and socioeconomic groups, but its diagnosis is not uniform across these groups. ASD is more common in males, but it is also suggested that girls who meet criteria for ASD are at higher risk of not being diagnosed. Females less likely present apparent symptoms and they more likely mask their social deficits through a process called "camouflaging". Children with ASD can also have common co-morbid diagnoses.

Children with ASD represent a challenge for dentists because of the prolonged physical contact and invasive procedures. [11] ASD impacts access to dental care because of difficulties in communication, altered sensitivity, etc. Children with ASD may present dental caries, traumatic injuries, sometimes self-inflicted, saliva drooling, bruxism, and a higher plaque index.

Sadly, even recent studies sustain the use of physical restraint for persons with intellectual disabilities or general anesthesia as the second option. While restraint is considered to be unethical by many healthcare professionals, general anesthesia bears a biological cost, in particular when dealing with the developing nervous system. Therefore, improving lifelong dental care by overcoming fear-related behaviour is advisable.

Examples of reported barriers to dental care access include aversion to dental treatment, complications associated with ASD, and problems with finding a practitioner willing to provide care. [12] Another complication is limited availability of dental specialists trained in treating patients with ASD. Unfortunately, it is common for children with ASD to be considered untreatable and uncooperative by dentists, or to be treated only with general anesthesia.

JAN z.s. [1] offers Early care for families with children diagnosed with ASD and communication deficiency, Social therapy provided free of charge to individuals on the whole autism spectrum and Social skills training group.

Mgr. Iveta Valentová, Ph.D., and Bc. Kateřina Dobrozemská from JAN are working to make dental care for children with ASD more accessible in the Olomouc Region and provide expert consultations during the development process.

Also, Bc. Kateřina Dobrozemská created a real dental office for training purposes, which I visited to gain inspiration. Mgr. Eva Čepičková, DiS., and Bc. Šárka Frankeová provide expert consultations during the testing phase.

After looking into ASD and JAN z.s., the following section will explore the potential role of VR in addressing healthcare challenges.

1.3 Applications of VR in healthcare

VR has recently gained popularity primarily in the gaming industry. Its immersive aspects make it suitable for applications in healthcare. [13]
There are two kinds of applications of VR in healthcare, emotion- and problem-focused solutions.

Emotion-focused solutions take user's attention away from the stressor, e.g., to distract children during a procedure to lower their emotional response.

Problem-focused solutions are considered exposure-based. Their objective is to help the user overcome the stressor itself through mental rehearsal, e.g., familiarising children with the process of the procedure.

After discussing broader applications of VR in healthcare, the following section will focus on its specific utility in addressing dental phobia and anxiety.

1.3.1 Applications of VR in dental phobia

Dental phobia and dental anxiety are common in society. Fear-related behaviours are difficult to manage and complicate proper dental care. [2] Patients with dental phobia often visit the dentist when the clinical situation is severe.

Two most effective therapeutic techniques for treating phobia are In Vivo Exposure Therapy (IVET) and Virtual Reality Exposure Therapy (VRET).
IVET, a standard therapy, requires direct patient confrontation with an object or series of anxious situations to reduce anxiety. VRET, an alternative to IVET, offers gradual exposure to sources of anxiety in VR environments. VRET can be a safer option as virtual representations can be better controlled, allowing patients to face them more gradually.

After discussing VR's efficacy in managing dental anxiety, let's look at its potential as a therapeutic tool for individuals with ASD.

1.4 Applications of VR in ASD therapy

VR platforms offer less stressful treatment. [7] Unpleasant experiences with communication and interaction in real situations may increase anxiety and lead to isolation. This negative impact can be minimized by VR. Also, VR interventions offer repeated practice, which is important to acquire social interaction skills. Unlike traditional methods that rely on memorization, VR offers learning by experiencing.

Having explored VR's benefits for individuals with ASD, let's explore a specific application known as Virtual Reality Social Cognition Training.

1.4.1 Virtual Reality Social Cognition Training (VR-SCT)

VR-SCT [7] offers VR-based practice of social scenarios including meeting new people, negotiating financial or social decisions, dealing with a roommate conflict, and a job interview. A feasibility study found that after 10 sessions of VR-SCT interventions, there were significant positive impacts in individuals with ASD. Recent investigation on the neural mechanisms of response discovered that such interventions also contribute to the strengthening of underlying brain networks that support their higher social functioning capacity.

Expanding on the benefits of VR-SCT, let's consider future directions for VR training systems for people with ASD.

1.4.2 Future VR-based ASD training systems

The benefits of VR for patients with ASD have been recognised since the 1990s. [7] Future efforts are possible in different areas, e.g., application expansion and improvement, technology enhancement, brain-based research and theoretical model development. This could benefit ASD population, reduce the workload of therapists, and facilitate the advancement of VR technology.

One option is to combine VR technologies with AI and machine-learning techniques to develop customized interventions. Automatic speech recognition and evaluation and automatic assessment of cognitive and emotional states should be embedded into VR training systems to measure and track user's abilities. This could ease the workload of therapists and offer services to more people.

Additionally, VR could be a part of big data that promotes worldwide collaboration on ASD research. VR training platforms are perfect for gathering big data owing to their capability to collect dynamic and detailed behavioral and neural data at various stages of training. Future VR training systems could be improved to record multi-level data, and allow uploading data to cloud storage. Researchers could develop VR-based multi-level ASD data repositories for research purposes. Such databases could be very helpful in providing comparison and reference for ASD assessment and diagnosis, as well as enhance our understanding of autism heterogeneity.

1.5 Requirements

This section outlines the essential requirements for the thesis.

The primary objective of this thesis is to design and implement a VR dental office environment in Unity. Within this VR environment, a child with ASD can experience a simulation of a dental visit with both a doctor and a nurse present. VR should allow the training of management of a difficult situation starting from entering the waiting room, proceeding to the dental office, sitting on a dental chair to dental exam. Methodical parts, specific processes and user interface (UI) elements were consulted with experts from JAN z.s. or others. The solution should enable a simple extension for additional training scenarios. The HTC Vive Pro VR set [14] is available with a tracking area of $2,5 \times 2$ meters.

It is crucial to emphasize that the VR environment is not intended to be recreational or entertaining. Rather, its sole purpose is for training. Therefore, there should not be elements of gamification present. The environment should be as similar as possible to a real dental office, including realistic dental equipment like a dental mirror.

The main goal is to familiarize children with ASD with the dental office environment. The simple presence of both the doctor and nurse in a dental office is challenging enough for them.

The child should be able to take the time needed to explore the environment of a waiting room. When the child is ready, they can meet with a nurse and doctor at the reception. The child should be able to spend as much time as needed in that new situation. When the child is ready, they can proceed to the dental office. After spending desired amount of time in the dental office, there should be an option to go back to the reception or leave. UI should prioritize simplicity and user-friendliness to ensure easy navigation for children with ASD.

After testing with experts from JAN z.s., the following requirements were added. The doctor and nurse should appear as human as possible, prioritizing realistic appearance over animations. The environment should contain decorations like plants and posters to make it more welcoming. The waiting room should have a visualization of time. It should be a countdown timer similar to those used in real-life waiting process training. This could be represented as a circle using a red color for the remaining time, with an option to extend the time as needed.

2 Existing solutions

In this chapter, examples of existing solutions are presented.

Keppy [4] is a VR-based product developed by 10X Immersive [15] founded in 2021 that helps dentists effectively distract patients. It improves patients' behavioral management and enables a safer environment for both patients and healthcare providers. Keppy is applicable for children and adults. It reduces stress and anxiety up to 65% and it has adaptive content developed by psychologists and pain management specialists. The technology uses Machine Learning (ML) algorithms to automatically adapt VR scenarios.

Keppy is made only for distraction purposes, not for training, and it is not specifically designed for children with ASD. Figure 1 presents the device and an example of the content. [4]

Figure 1: Keppy

"A Virtual Dental Office Experience for Children With ASD" [6] is an ongoing study with the objective to evaluate the effectiveness of VR (360° video) compared to a social story for reducing dental anxiety in children with ASD. The 360° video is developed by Shaftesbury Films in consultation with Holland Bloorview dental, research staff, and family advisors. Participation in this research study includes daily at-home use of either the 360° video (experimental condition) or social story (control condition) for seven days prior to the participant's first visit to the dental clinic. Both pre-visit experiences are delivered through the use of a study-provided tablet. The 360° video is from the point of view of a seated dental patient and the participant is able to explore the scene around them through the tablet's touch screen. The simulation includes scenes/features that may be anxiety-provoking. These include loud noises commonly encountered in the dentist's office, social stimuli like a dentist, etc.

This study uses a 360° video on a tablet simulating a seated dental patient. It is made for training purposes. It is not an immersive experience, as it does not use a VR headset. The waiting room is not included in the training, and the video includes noises designed to prepare the participant for a visit to the dental clinic. It is specifically designed for children with ASD. Figure 2 is a screenshot of a 360° video. [16]

Figure 2: A Virtual Dental Office Experience for Children With ASD

Virteasy Dental [5] is a dental simulator developed for students that combines VR and haptics. It is integrated on Unreal engine. Students can perform treatments on a fully virtual patient in a virtual scene and more.

This dental simulator is designed for students, not for patients. However, it is worth mentioning as it is an interesting tool using VR for creating a virtual dental office environment. Figure 3 demonstrates the dental simulator. [17]

Figure 3: Virteasy Dental

3 VR development

This chapter presents central definitions and describes the main phases of creating a VR project, along with the tools and skills required. Basic VR development requirements include target VR headset and accessories, advanced computer hardware, game engine, VR software development kits and 3D models.

3.1 XR

Augmented Reality (AR), Virtual Reality (VR), Mixed Reality, and Extended Reality (often misleadingly abbreviated as XR) are commonly but inconsistently used terms to describe how technologies generate or modify reality.

Definitions of terms were discussed and organized by experts in the proposed framework [18]. In conclusion (1) XR should not be used for extended reality, but X should imply the unknown variable: xReality; (2) AR and VR have fundamental differences and should be treated as different experiences; (3) AR experiences are described on a continuum ranging from assisted reality to mixed reality (based on the level of local presence); and (4), VR experiences can be conceptualized on a telepresence-continuum ranging from atomistic to holistic.

More formally, telepresence is defined as the degree to which a user feels present in the virtual environment rather than the physical.

On one hand, atomistic VR refers to applications of VR for which the quality of the user experience is often secondary to some other goal. In these cases, the user's perception of telepresence is less important than accomplishing a specific goal. On the other hand, VR experience in holistic VR is nearly indistinguishable from a real-world experience.

3.2 VR devices

Multiple VR devices with various properties are available. VR headsets have two different types of tracking: outside-in and inside-out. [19], [20] With outside-in, an external device is tracking the VR headset and the controllers. Outside-in allows room-scale tracking with more accuracy. Inside-out tracking uses sensors or cameras on the headset itself. Another distinction is PC VR (Tethered VR) headsets and AIO VR (All-in-one/Standalone VR) headsets. First class requires a powerful PC to run and can handle larger models with better performance. Standalone VR headsets are wireless and they are suited for smaller models.

The headset chosen for this project is the HTC Vive Pro [14], due to its availability at Palacký University Olomouc. It is a tethered VR headset and it uses base stations for tracking. The HTC Vive Pro was not designed to be used by young children. Older children should be monitored closely by adults for any negative effects during and after their use of the product. Older children are not allowed to use the product if negative effects are observed. VR headsets are generally recommended for children older than twelve years, due to developmental factors and more. Additionally, Meta Quest 3 was available for testing. [21]

3.3 VR ready HW

Once the target device is known, the next step is getting the HW ready for VR development. SteamVR Performance Test [22] and Vive Quick Compatibility Check [23] test system performance for VR. This project is developed on Windows 10 with AMD Ryzen 7 5800H with Radeon Graphics 3.20 GHz CPU and NVIDIA GeForce RTX 3060 Laptop GPU.

Beside system requirements there are also different requirements for USB Ports and Video Output. Next phase after meeting computer requirements is setting up the space in room for VR.

3.4 Game engine

A game engine unites all aspects of creating a game. Some of these aspect relevant to this project are 3D models, textures, scripts, animation and audio. [24] There are two leading game engine options, Unity [8] and Unreal [25]. Unity has been on the market since 2005, and it is one of the most stable game engines available. Unity supports a range of software development kits (SDK), application programming interfaces (API) and other integrations for all the major VR devices. Unity is considered more beginner friendly and uses C# for programming. [26] Unreal is a more complex and sophisticated tool compared to Unity and uses C++. Unity was chosen for this project.

3.5 VR SDKs

Virtual reality software development kits, or VR SDKs, provide the fundamental tools to create VR experiences. [24] SDKs enable to perform functions such as adding, cloning, and moving objects. While SDKs are typically intended for specific frameworks and HW, some can be supported on multiple systems.
Some of the popular SDKs are Viveport SDK, Oculus SDK, OpenVR SDK, PSVR Dev kit.

3.6 Steam and SteamVR

Steam [27] is a video game digital distribution service and storefront by Valve. SteamVR [28] is a virtual reality hardware and software platform developed by Valve, with a focus on allowing room-scale experiences using positional tracking base stations. SteamVR was first introduced for the Oculus Rift in 2014, and later expanded to support other virtual reality headsets, such as the HTC Vive.

4 Real-time creation process

This chapter provides a detailed look at the real-time creation process. The main source of information is Unity Learn [24] and Unity Documentation [29]. Unity Learn offers free learning materials in form of tutorials, courses and guided pathways to help master VR development and other skills.

4.1 Unity Essentials

This part introduces essential tools in Unity [8], detailing assets used in this project. Unity Hub [30] is an essential tool for managing projects and versions of the Unity Editor. There are different types of Unity releases, Long-Term Support (LTS) releases and TECH Stream releases, including alpha and beta releases. The latest LTS version 2022.3.4f1 was chosen for this project, as it is generally recommended. New projects can be created using templates. Templates have preselected settings and feature sets based on common best practices. This project uses VR (URP) Core template. The URP (Universal Render Pipeline) allows quick and easy iteration with optimised graphics.

The default Unity Editor layout is organized with windows. In the center is the Scene view. This is an interactive window into the created world. The Scene view is used to view and manipulate objects. Game view also appears in this area and it serves to playtest the game. GameObjects, all objects in the current Scene from the game world, are organized in the Hierarchy window. The Project window works as a file explorer, organized in folders, and it contains all the files (assets) available for use. Selected GameObject in the Scene view or in the Hierarchy has its components in the Inspector. Components describe the properties and behaviors of GameObjects. The toolbar buttons can change the point of view in the Scene, start and stop Play Mode and more.

Projects are organized into scenes. Scenes contain everything in the created experience. Scenes can be considered discrete experiences. For example, the game's main menu could be one scene and each level in a game could be another separate scene. Navigating in the Scene view is very important.

The term real-time describes how quickly an image is rendered (or displayed) on the screen. For tool sets like Unity, real-time interaction occurs for both creators and end-users.

It is possible to create primitive objects, placeholders, inside a game engine, but assets, objects which make the unique interactive experience are created by artists in external programs called Digital Content Creation (DCC) tools. Ready-to-use assets created with DCCs are available at the Unity Asset Store. It is possible to download and import assets directly into the project using a link between the Asset Store web site and the Package Manager in the Unity Editor, via Unity ID.

Doctor and nurse characters shown in Figure 4 are made by Metastage. Using 106 cameras, Metastage records a person from every possible angle, and reconstructs it to form a high quality, fully 3D asset. Users can experience real people with real actions and emotions.

Hospital asset with optimized 3D models is made by Blue Dot Studios. Doctor and nurse characters ready to be used with animations are made by New Punch Studio. Animations are made by Jasirkt. UI components are made by Epibyte. Countdown timer is made by Hamza Herbou.

It is critical to make sure that selected assets will be compatible with chosen version of Unity.

Figure 4: Doctor and nurse assets from Metastage

4.2 Set up for VR

Set up for VR is necessary to enable VR development in the project.

Firstly, the `OpenXR` [31] package should be installed. This allows to publish to a wide range of devices using a single plugin. The interaction profile should be set up to resolve warnings.

In order to develop the project, the `XR Interaction Toolkit` [32] package should be installed. This allows to quickly develop XR interactions. Additionally, helpful samples for quick development need to be installed. `Starter Assets` which provide a set of `Default Input Action presets` for mapping specific buttons to actions using the action-based input system have to be imported. The `XR Device Simulator` [33] has to be imported for testing VR application using keyboard and mouse controls instead of an actual headset.

To set up the action-based input system in the Scene, XR Input Action Manager object should be in the Hierarchy. The Input Action Manager component has to be added to the object. The new Action Asset should be added and the XRI Default Input Actions preset should be assigned to Element 0.

To apply action presets automatically when adding XR components, each default action preset in Starter Assets folder should be selected and at the top of the Inspector for each one, Add to [component] Default should be selected.

Then, it should be ensured that new XR GameObjects use the appropriate presets in Preset Manager panel, ActionBasedController section.

An action-based XR Rig has to be added to the Scene by creating an XR Origin (VR) in the Hierarchy. This object contains the camera and controllers for the user.

5 From an empty scene to hospital in VR

The following chapter shows the progress from an empty scene in Unity to hospital in VR. Also, it presents solutions to main obstacles. The main source of information is Unity Learn [24] and Unity Documentation [29].

5.1 Creating a scene with assets

The best suitable assets can be found at the Unity Asset Store [34]. Selected assets must be compatible. Assets should have good reviews, ratings and documentation. Downloaded and imported assets are in the Project window and ready to be used in the Scene.

Creating a scene according to requirements can be an interesting but long process. To speed up the process, a scene from the Unity Asset Store can be imported and adjusted with other assets to meet requirements. The time can be used to pay attention to details instead.
The game is play tested using Game view and the XR Device Simulator.

5.2 XR Device Simulator

The XR Device Simulator settings are in Edit, Project Settings. The XR Interaction Toolkit should be selected in the XR Plug-in Management. "Use the XR Device Simulator in scenes" has to be checked. In the Inspector of the Right Controller, in the XR Controller component, the Model Prefab should be set to XR Controller Right. Any changes made in Game view are not saved.

5.3 Pink, gray and blocky assets

One problem is when assets have pink color as it is shown in Figure 5 . To fix this problem, materials should be converted to URP. This can be done by selecting pink materials presented in Figure 6 and converting `Selected Built-in Materials to URP` in `Edit`, `Rendering` and `Materials`.

In case the material was not upgraded, because there's no upgrader to convert shader to selected pipeline, the `Shader` can be changed to `Universal Render Pipeline` in the `Inspector` of the selected pink material.

If the material changed from pink to gray, the `Base Map` should be set to the texture for that material.

Figure 5: Pink & gray & blocky doctor

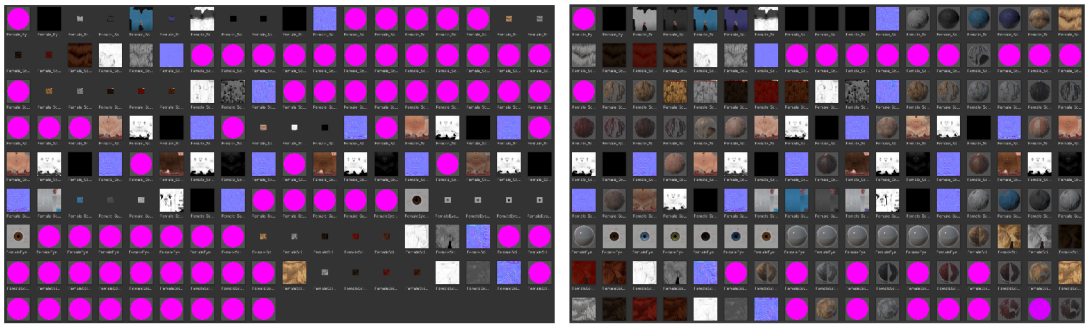

Figure 6: Pink materials

Another problem is with blocky eyelashes etc., demonstrated in Figure 5. To solve this problem, the `Alpha is Transparency` box should be checked in the texture and the `Transparent Surface Type` should be selected in `Material`.

Unfortunately, these problems appear in different versions of Unity. Hopefully, it will be fixed in the next one.

When all materials are fixed, the avatar can be customized. There are different options of hair color and style, skin tone and clothes. Also, this avatar has a skeleton.

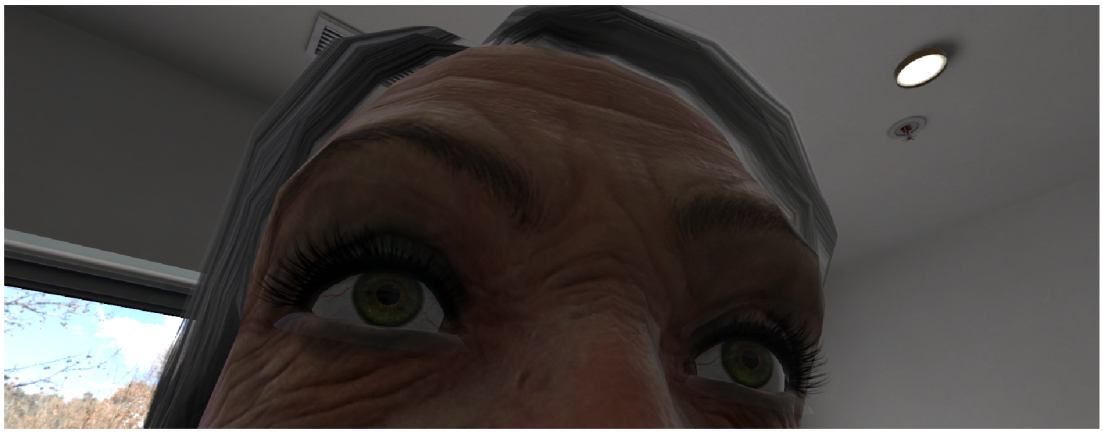

Figure 7: Mecanim Ready doctor with fixed eyelashes

5.4 Animations with Mecanim

Avatars with humanoid skeletons work with animations. This avatar shown in Figure 7 is `Mecanim Ready`, which means it works with `Mecanim compatible` animations. [35] Mecanim is a sophisticated animation system in Unity. Mecanim provides easy workflow and setup of animations on humanoid characters and more. Mecanim is recommended for use in most situations, especially for working with humanoid animations.

At the end, doctor and nurse holograms presented in Figure 8 were chosen to be used, because they are 3D captures of real people. These assets are without skeletons, but animations are not needed at the moment. The subtlety of human motion is represented in these models, bringing authenticity to the digital environment. In these looping captures, doctor and nurse listen to an imaginary speaker. The format is .mp4 mesh texture wrapper. However, there are also `Mecanim Ready` assets ready to be used in case of need.

Workflow in Mecanim can be divided into three phases. Asset preparation and import, Character setup for Mecanim and Bringing characters to life. `Animator` makes characters alive, it is an interface to control `Mecanim animation system`. `Animation State Machines` can be set up from the `Animator Controller Window`.

`State Machines` consist of `States`, `Transitions`, and `Events`. An `Animator Controller` should be created for each character and added to its `Inspector`. Animations are assigned to characters in the `Animator` component.

Figure 8: Doctor and nurse at the reception

The `Animator` component requires a reference to an `Animator Controller` which defines which animation clips to use, and controls when and how to blend and transition between them. Humanoid characters with an `Avatar definition` should have the `Avatar` assigned in this component.

`Transitions` are used in the state machine to switch from one animation state to another. `Transitions` define the duration of the blend between states and conditions when a transition occurs. To set these conditions, values of parameters have to be specified. To view properties of a transition, the transition line connecting two states must be selected. `Transitions` can have a single condition, multiple conditions, or no conditions.

Doctor and nurse have simple animations. They both perform natural body movements and gentle gestures with their hands.

5.5 UI

All UI elements must be children of the `Canvas`. The Canvas area is visible as a rectangle in the `Scene View`. The `Canvas` uses the `EventSystem` object to help the `Messaging System`. The `EventSystem` should use the `XR UI Input Module`. The `Render Mode` setting in the `Canvas` can be used to make it render in different types of space. `World Space` render mode is useful for UIs that are meant to be a part of the world. The `Tracked Device Graphic Raycaster` component should be added to the `Canvas` to make UI interactable in VR.

There are two buttons in the dentist room, `Reception` and `EXIT`. The same two buttons are in the waiting room. There are two more buttons at the reception, `Dentist` and `EXIT` shown in Figure 9.

The Dentist button teleports the player to the dentist room and the Reception button teleports the player to the reception. The EXIT button exits the game. All of them have highlighted version of the color. Buttons can be play tested using the XR Device Simulator with mouse and keyboard. The button can be pressed with mouse or using the right controller. Toggling 'Y' or holding 'Space' on the keyboard manipulates the right-hand controller. Left click with the mouse on the highlighted button simulates the trigger button.

Figure 9: Dentist button, highlighted

Creating a button is simple, but using some prefab is faster. It can be scaled and customized. A C# script with a desired function for the button should be dragged to an empty object in the Hierarchy. In the Inspector of the button, the object with the script should be added to the OnClick and the desired function should be selected.

Input tracking and input actions should be enabled in the Inspector of the Right Controller and the UI Select and UI Press Action should be set. The reference to XRI RightHand Interaction/UI Select (Input Action Reference) and XRI RightHand Interaction/UI Press (Input Action Reference) should be used.
In the XR Ray Interactor, the Interaction Manager must be set to XR Interaction Manager and "Enable Interaction with UI Game Objects" has to be checked. Also, Max Raycast Distance in the Raycast Configuration of the XR Ray Interactor can be adjusted. The Right Controller can press all buttons.

The XR Interactor Line Visual in the Inspector of the Right Controller can be edited. The Line Width, Valid Color Gradient, Invalid Color Gradient, Line Length and more can be set to desired values. To make a white line appear only when pointing towards a button, the Alpha should be reduced to 0 in Invalid Color Gradient. The Valid Color Gradient should be set to white.

The Left Controller is not needed. In the top of the Inspector of the Left Controller, Left Controller should be unchecked.

Traditionally, games have a main menu. There are many discussions about menus in VR. There are options and assets. Some menus are in a separate scene, but it is not a rule. The main menu adds more interactions with a user and maybe even another scene. After trying different options, importing different menus and customizing them, the right choice is a simple one. There is no menu needed. These few buttons make a simple and sufficient UI. Also, these few buttons are similar to real signs used in hospitals. There is no rule about menu in VR, but there is a well known KISS principle in design. Keep it super simple.

After testing, experts from JAN z.s. suggested that the waiting room should have a visualization of time. It can be a countdown timer represented as a circle using a red color for the remaining time. There should be an option to extend the time. This can be realized analogically to the creation of the previous buttons described above. A small change was made to the `Reception` button. Pressing the `Reception` button in the waiting room starts the countdown timer. The default time is 30 seconds. Pressing the countdown timer adds 30 seconds to the remaining time. When the remaining time is zero, the teleport to the reception happens.

5.6 Teleportation

The `Dentist teleport` and the `Reception teleport` are two empty objects in the `Hierarchy`. The most straightforward way to implement teleportation is to create a C# script that changes the position of the `XR Origin` to the `Dentist teleport` or the `Reception teleport`. This works well with the `HTC Vive Pro` headset due to the limited area of movement. However, `XR Interaction Toolkit` offers a better approach.

The `Locomotion System` and the `Teleportation Provider` should be added to the `XR Origin` to enable teleportation. Also, the `XR Origin` should be added to the `Locomotion System`. Then, the `Locomotion System` should be added to the `Teleportation Provider`.
The `Teleportation Anchor` should be added in the `Inspector` of the `Dentist button`. The `Interaction Manager` and the `Teleportation Provider` should be added in the `Teleportation Anchor`.
The `Interaction Layer Mask` should be set to `Teleport`. The `Teleport Anchor Transform` can be defined as the `Dentist` teleport. Then, the `Snap Volume object` must be added to the `Dentist` button. It should be a `XR Interactable Snap Volume` with a `Box Collider` that `Is Trigger`. The process can be repeated for the `Reception` button. `Input Actions` and controller bindings can be customized in the `XRI Default Input Actions`. The `triggerPressed [RightHand XR Controller]` should be added to the `Teleport Select` and `Teleport Mode Activate` actions in the `XRI Right Hand Locomotion Action map`. Also, the `Action Type` should be set to `Button` in the `Action Properties`.

The Teleport Interactor object must be added to the Right Controller and its Layer should be set to Teleport. The Select Action and the Select Action Value should be set to XRI RightHand Locomotion/Teleport Select (Input Action Reference) in the XR Controller (Action-based) of the Teleport Interactor. The Line Bend Ratio should be set to 1 in the XR Interactor Line visual in the Inspector of the Right Controller, to keep the line straight during teleportation.

Finally, the Layer is set to UI in theInspector of the Reception button in the waiting room. The C# script that starts the timer was edited to create new Teleport Request when the timer ends. The Interaction Layer Mask of this Teleport Anchor should be set to Nothing. Also, Snap Volume of this button should be unchecked.

The latest XR Interaction Toolkit 3.0.4 [32] should offer a new way to move and manipulate the XR Origin. The LocomotionSystem has been deprecated and replaced by the LocomotionMediator. XR Body Transformers allow specific types of manipulation of the XR Origin and can be queued up by the new LocomotionMediator. The Teleportation Anchor Interactable has a specialized implementation of the GenerateTeleportRequest method.
However, XR Interaction Toolkit 2.4.3 is used in this project, as it is recommended. 3.0.4 version was used for experimenting.

5.7 Lighting

When Unity calculates lighting at runtime, it is called Real-time lighting. Baked lighting is when Unity performs lighting calculations in advance and saves the results as lighting data. Lighting data is then applied at runtime. Lightmapping is the process of pre-calculating the brightness of surfaces in a Scene, and storing the result in a texture called a lightmap. The mix of these two types of lighting is called mixed lighting.

5.7.1 Lightmaps and Lightmap UV overlap

After adding all assets into the Scene, the lighting should be generated to fix problems with lightmaps. It can be done by opening the Lighting window and selecting Generate Lighting. This generates lightmaps for the Scene. Lightmaps are saved in GI Cache. Cleaning the cache should only be done as a last resort. In the Lighting window, the baked data can be cleared in a Scene.

Each lightmap contains charts. Unity maps these charts onto mesh faces, and uses the charts' lighting data to calculate the final appearance. Data from one chart can bleed onto another if they are too close. The way GPU sampling works can cause this problem. Lightmap UV overlap usually leads to unintended artifacts such as aliasing, pixelation, and so on.

If Unity detects overlapping UVs, it prints a warning message. There is no one single solution for UV overlap, because there are many things that can cause it. One of the most common solutions to consider is to increase the pack margin. If Unity automatically generates the lightmap UVs for a Model, the Model can be selected in the Project view. The Geometry section is in the Model tab of the Model Import Settings in the Inspector. The Lightmap UVs settings section appears below the Generate Lightmap UVs checkbox. The Margin Method should be set to Calculate, and an appropriate Min Lightmap Resolution and Min Object Scale should be configured. Another way is to set Margin Method to Manual and adjust the Pack Margin value directly. Different approach is to increase the resolution of the entire lightmap. This increases the numbers of pixels between the charts, and therefore reduces the likelihood of bleeding. The downside is that the lightmap may become too large. This can be done in the Lighting window under Lightmapping Settings. Finally, it is common practice to ignore these warnings if there are not any visible artifacts. There were 467 objects in the Scene with overlapping UVs. After applying all of the mentioned approaches, there are 32 objects in the Scene with overlapping UVs now. These objects can be ignored.

5.7.2 Perspective aliasing

The problem where shadows from Directional Lights appear pixelated when they are near the Camera is called Perspective aliasing. Shadow Cascades can help solve this problem. The more cascades are used, the less are shadows affected by perspective aliasing. Increasing the number of cascades increases the rendering overhead. In the URP, Shadow Cascades configuration is in the Universal Render Pipeline Asset. Also, Perspective aliasing is less noticeable when using Soft Shadows, and with a higher resolution for the shadow map.

5.8 Optimization

There are a few techniques to implement when optimizing VR applications. Firstly, Light baking reduces the computational expense of rendering the Scene. Occlusion Culling is another technique used to reduce the workload of the GPU. Occlusion Culling is a process which prevents performing rendering calculations for GameObjects that are completely hidden from view by other GameObjects. GameObjects should be identified and selected as Static Occluders and Static Occludees. Then, the Occlusion Culling window can be opened by selecting Window and Rendering. The Bake button is in the Bake tab. Static batching improves GPU and CPU performance. By tagging all stationary objects as static, Unity combines stationary GameObjects into one big Mesh, rendering them faster. Also, static objects do not need to be included in physics calculations.

Quality settings in Project Settings control the graphical quality of objects being rendered. The lower the graphical quality, the higher the performance. Finally, the right rendering mode should be selected. Single-pass instanced is the most performant rendering mode.

5.9 Android, Meta Quest and Oculus XR Plugin

To support Android, a Unity project requires Android Build Support module, Android Software Development Kit [36], Native Development Kit [37] and Java Development Kit which is by default OpenJDK [38]. The three modules can be installed in Unity Hub.

OpenXR Plugin offers the Meta Quest Support feature. [21] The OpenXR settings page can be opened under XR Plug-in Management. The Oculus Touch Controller Profile should be added to the Interaction Profiles list. Meta Quest Support can be enabled under OpenXR Feature Groups. The Android apks that are produced with Quest support enabled can run on the Quest family of devices.
Oculus Integration package features are not available in OpenXR Plugin. However, Oculus XR Plugin can be used in case of need. [39]

5.10 Build

Unity can build the application for different platforms and with different settings. The settings for application's build can be adjusted in File and Build Settings. Management of Scenes that should be included in the build is in Build panel. The Platform section of the window can be used to select a platform to built to. The Build or Build And Run button can be selected.

6 Other problems with Unity

This part addresses other problems encountered while using Unity.

6.1 OnValidate warnings

Unity users often encounter the warning "SendMessage cannot be called during Awake, CheckConsistency, or OnValidate." These warnings usually do not affect functionality. The best solution appears to be simply ignoring them. Other solutions are considered suboptimal workarounds. This has been a persistent issue in Unity since 2018.

6.2 Inconsistent result for asset warnings

Another common warning is: "Importer (NativeFormatImporter) generated inconsistent result for asset 'Assets/XR/Settings/Open XR Package Settings.asset'." This problem has been unresolved since 2021. Currently, users are waiting for a fix from Unity.

6.3 Hold on messages

Since Unity 2020, users have experienced frequent "Hold on" messages. These messages appear regardless of the project size, sometimes taking hours to resolve. This problem has significantly affected user productivity by slowing down the development process.

6.4 Connection to HTC Vive Pro

The SteamVR app must always be open to run the VR on the HTC Vive Pro. To solve problems with the connection to the HTC Vive Pro, verify that all software, including Unity Hub, Unity, Steam, SteamVR, OpenXR, and XR Interaction Toolkit, etc. is installed and updated. Ensure that the `Play Mode OpenXR Runtime` is set to SteamVR in `Project Settings`. Check all `Project Settings` from Project Settings. Within the SteamVR app settings, confirm that the Current `OpenXR Runtime` is set to SteamVR. Restart everything. Reinstall all related software. If the problem persists, create a new Unity project to rule out any project-specific issues. While not as frequent as other issues, connection problems with the HTC Vive Pro can still occur.

7 User documentation

User documentation offers a description of the software, including recommended system requirements, the installation process, and a user guide. Information about the HTC Vive Pro is sourced from Vive Pro Support. [14]

7.1 Introduction

This software is a dental office environment in virtual reality developed in Unity for the HTC Vive Pro. Virtual reality allows user to train for the waiting process using a visualization of time in the waiting room, meet with the dentist and nurse at the reception, proceed into the dental office or leave, explore the dental office, and familiarize themselves with it in detail. The dentist and nurse are present in the dental office, and the user has the option to return to the reception at any time or leave.

Recommended system requirements:

- **Processor:** Intel Core i5-4590/AMD FX 8350 equivalent or better
- **GPU:** NVIDIA GeForce GTX 1070/Quadro P5000 equivalent or better, AMD Radeon Vega 56 equivalent or better
- **Memory:** 4 GB RAM or more
- **Video output:** DisplayPort 1.2 or newer
- **USB port:** 1x USB 3.0 or newer
- **Operating system:** Windows 10, Windows 11

7.2 Getting started

1. **Install Steam and SteamVR:** Download and install Steam and SteamVR.
2. **Connect HTC Vive Pro:** Connect the HTC Vive Pro to the computer. Necessary drivers will be installed when connecting it for the first time.
3. **Pair Controllers:** Follow the on-screen instructions to pair controllers.
4. **Room Setup:** Complete the Room Setup to define the play area. Ensure that base stations are powered. Check that Vive hardware is tracked.
5. **Run the VR app:** Open the SteamVR app and launch the VR application. To run VR on the HTC Vive Pro, keep the SteamVR app open.

7.3 Using VR

1. **Starting point:** Begin in the waiting room. Look around and spend there as much time as needed. Figure 10

2. **Navigation to reception:** Use the trigger button on the right controller to press the Reception button to move to the reception or press the EXIT button to exit VR. Figure 11

3. **Waiting process training:** Train for the waiting process with the countdown timer. The countdown starts by pressing the Reception button. Start with the 30 seconds long default waiting time. Use the trigger button on the right controller to press the countdown timer and prolong the remaining waiting time by 30 seconds. Figure 12 and Figure 13

4. **Meet reception staff:** Meet the dentist and nurse. They are listening. Figure 14

5. **Navigation to dentist room:** Use the trigger button on the right controller to press the Dentist button to move to the dentist room, or press the EXIT button to exit VR. Figure 14

6. **Exploring dentist room:** In the dentist room, the doctor and nurse will be present. Explore the room and its details. Figure 15 and Figure 16

7. **Exiting VR:** Use the trigger button on the right controller to press the EXIT button to exit VR or press the Reception button to return to the reception. Figure 17

Steam VR menu can be turned on/of by the System Button press on the controller. This can be enabled in SteamVR Settings. Set On the VR Dashboard on System Button.

Figure 10: Waiting room

Figure 11: Navigation to reception

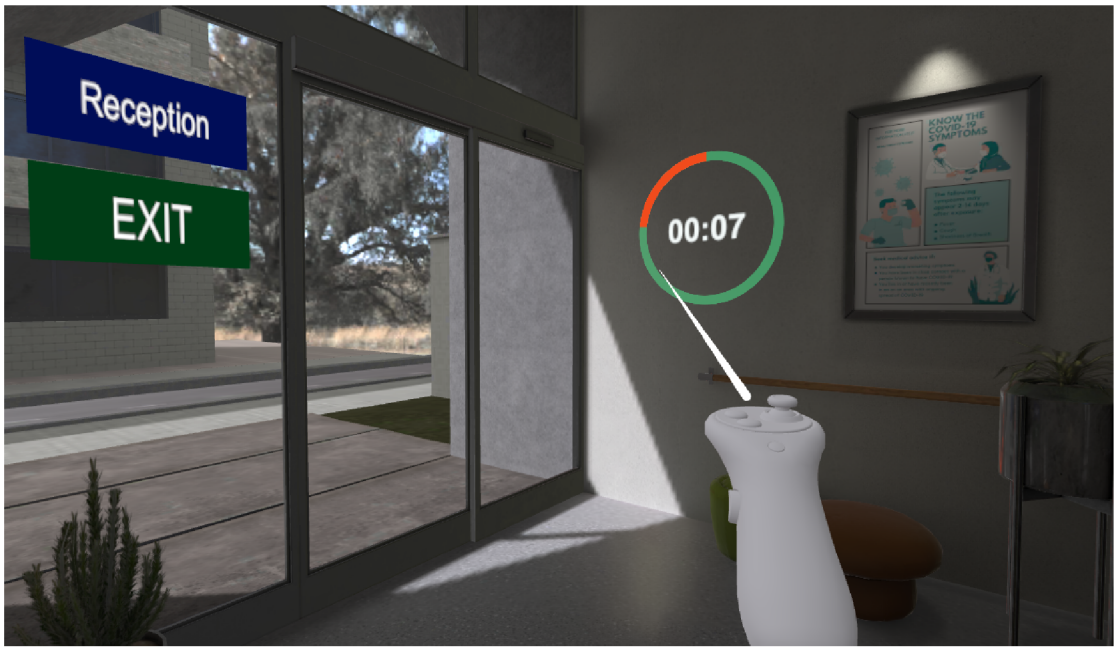

Figure 12: Waiting process training

Figure 13: Waiting process training

Figure 14: Reception

Figure 15: Exploring dentist room

Figure 16: Exploring dentist room

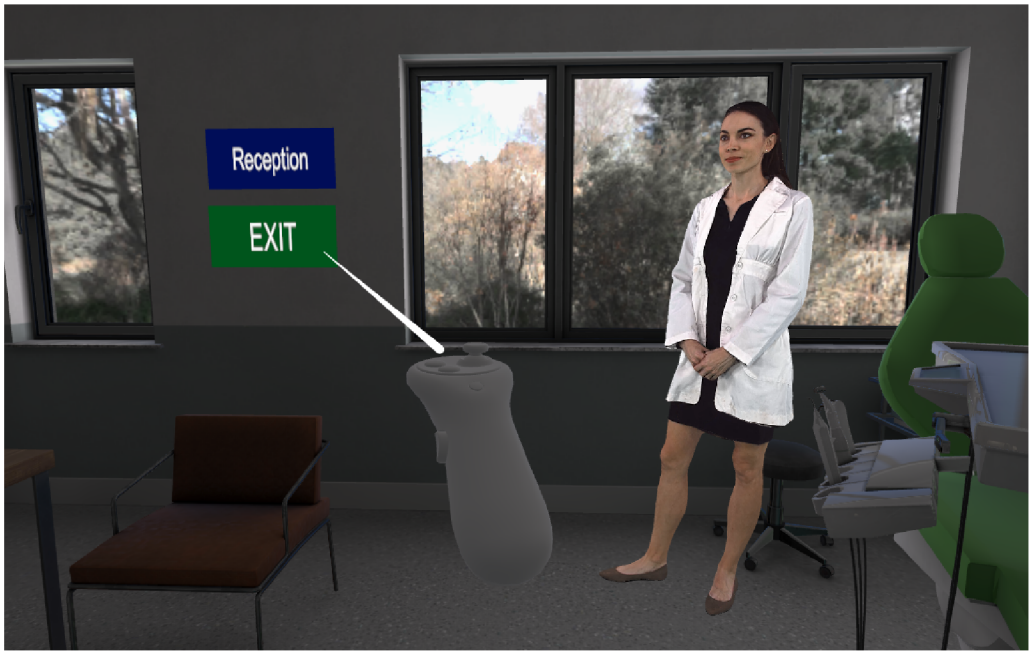

Figure 17: Exiting VR

8 Technical documentation

Technical documentation outlines the software requirements, key files and directories, project settings and asset management. It also provides guidance on VR integration, the animation system, UI, lighting and optimization.

8.1 Software requirements and project setup

- Unity Hub
- Unity LTS 2022.3.4f1 in Unity Hub
- Visual Studio
- Game development with Unity in Visual Studio

Step-by-step instructions to set up the project are included in README.txt.

8.2 Directory structure, key files and directories

- Assets
- Build
- Library
- Logs
- Packages
- ProjectSettings
- UserSettings

Key files and directories:

- Assets
- Assets\Blue Dot Studios\Hospital\Scenes\BDS_Hospital_URP
- Build\bp.exe

The `Assets` directory contains all imported assets. BDS_Hospital_URP is the main scene. bp.exe is a VR executable file.

8.3 Project settings

Go to `Edit`, then `Project Settings`. `OpenXR` in `XR Plug-in Management` should be checked. In `XR Plug-in Management` go to `OpenXR`. Set the `Render Mode`. Multi-pass is better for VR, and in this mode, Unity performs a render pass for each eye. Multi-pass mode provides the widest compatibility with existing shaders and rendering utilities, but is slower. In Single-pass instanced mode, Unity renders the scene in a single pass. This mode greatly decreases CPU usage and slightly decreases GPU usage. Set the `Play Mode OpenXR Runtime` to SteamVR. The `Play Mode OpenXR Runtime` setting is not saved between Editor sessions. It reverts to the System Default option on exit. When the mouse is held over the drop-down control for the `Play Mode OpenXR Runtime` options, the tool-tip shows the path to the selected `OpenXR runtime`. Ensure that the `HTC Vive Controller Profile` is added in `Interaction Profiles`. In `XR Interaction Toolkit` check `Use the XR Device Simulator` in scenes to playtest VR in Unity. Do not use the `XR Device Simulator` for the build.

8.4 Asset management

Go to `Window`, then Package Manager. See packages in Unity Registry, In Project, My Assets and Built in. `Upload` or `Remove` them. Install new packages. Find new assets in `Unity Asset Store`. All imported assets in the Assets directory can be used in the project. To use the prefab asset, drag it to the opened BDS_Hospital_URP scene. Figure 18

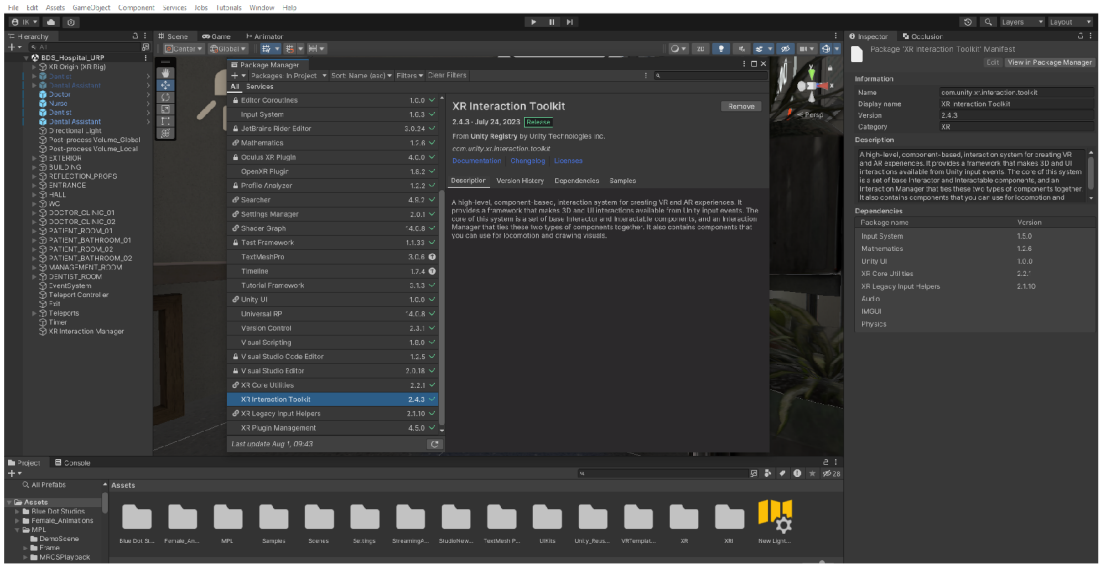

Figure 18: Unity editor, Package Manager and Assets directory

To customize characters, select the object in the Hierarchy or in the Scene. Set the properties in the Character Customize component. There are five Face Types, seven Skin Types, six Eye Colors, four Top and Btm Colors, five Hair Types and Hair Colors. These assets are from Studio New Punch.

To add another characters like Doctor and Nurse from the reception to the Scene, navigate to MPL\MRCSPlayback\Prefab and drag the HoloVideoExamplePrefab object into the Hierarchy.
With the HoloVideoExamplePrefab selected in the Hierarchy, locate the Holo Video Object script in the Inspector. In the URL field, type the name of the Performance Library .mp4 file located in the StreamingAssets folder. Include the .mp4 file extension at the end of the URL. Auto Graphics API in the Player settings on the Android platform should be unchecked. OpenGLES3 [40] should be the first one in Graphics APIs.

8.5 VR integration

Besides settings mentioned in Project Settings, ensure that ActionBasedController section in Preset Manager panel contains appropriate presets. Also, XRI Default Right Controller should be labeled as Right and XRI Default Left Controller should be labeled as Left. Also, in Player configuration, Action Input Handling should be set to Input System Package (New) or Both. The action-based XR Rig should be in the Scene. It contains the camera and controllers.

8.6 Animation system

Assets\Female_Animations\Animations contains Animator_Dentist.controller file and Animator_Assistant.controller file. The Animator component of Dentist character has a reference to Animator_Dentist.controller and analogically with the Dental Assistant character. Animation State Machines can be set up from the Animator Controller Window.

8.7 UI and teleportation

UI Buttons Canvas in Dentist Room and Entrance contain buttons. Buttons have to be children of the Canvas. The Canvas should use the World Space render mode. The Tracked Device Graphic Raycaster component should be added to the Canvas. The EventSystem should use the XR UI Input Module. Add new buttons using prefabs or create new ones.

Assets\UIKits\Scripts contains Exit.cs script. Exit object in the Hierarchy has the Exit.cs script in it. Buttons use the Exit object in OnClick.

Dentist teleport and Reception teleport are empty objects used for teleportation. Position them in the Scene correctly. Create new teleport objects and add them to Teleports object.

Input actions and input tracking should be enabled in the Right Controller. XRI RightHand Interaction/UI Press (Input Action Reference) should be referenced in the UI Press Action. XRI RightHand Interaction/UI Select (Input Action Reference) should be referenced in the UI Select Action. In the XR Ray Interactor the Interaction Manager should be set to XR Interaction Manager and interaction with UI Game Objects should be enabled. Max Raycast Distance in the Raycast Configuration of the XR Ray Interactor should be adjusted.

In the Inspector of the Right Controller, edit XR Interactor Line Visual to change the appearance of the controller's line. In the XR Controller, the Model Prefab should be set to XR Controller Right. At the top of the Inspector of the Left Controller, check the Left Controller if needed.

Assets\Unity_ReusableTimers-master\Assets\Timers contains Timer.cs and TimerStart.cs scripts. Timer object in the Hierarchy has the TimerStart.cs script in it. In the Hierarchy, Entrance contains the UI Timer Canvas and the Timer UI V4 object in it. The Timer UI V4 uses the Timer object in OnClick. The UI Buttons Canvas contains the Reception Button, it uses the Timer object in OnClick, too.

In the Inspector of the Dentist button, in the Teleportation Anchor component, define the Teleport Anchor Transform as the Dentist teleport or other. Analogically for the Reception button. Customize Input Actions and controller bindings in the XRI Default Input Actions. In the Inspector of the Right Controller, set the Line Bend Ratio. In the Inspector of the Teleport Interactor, the Select Action and the Select Action Value should be XRI RightHand Locomotion/Teleport Select (Input Action Reference) in the XR Controller (Action-based).

8.8 Lighting and optimization

Go to Window and Rendering. Open the Lighting window to Generate Lighting. Edit the resolution of the lightmap under Lightmapping Settings. In the Inspector of the Model, the Lightmap UVs settings section appears below the Generate Lightmap UVs checkbox. Assets\Blue Dot Studios\Hospital\Settings contains UniversalRP-HighQuality.asset. Configure shadows using this file.

GameObjects should be identified and selected as Static Occluders and Static Occludees. Open the Occlusion Culling window by selecting Window and Rendering. Select the Bake tab and press the Bake button. All stationary objects should be tagged as static. Configure Quality settings in Project Settings. Adjust the rendering mode. Single-pass instanced is the most performant rendering mode.

8.9 Meta Quest Support and Oculus XR Plugin

Open the OpenXR settings page under `XR Plug-in Management`. The `Oculus Touch Controller Profile` should be added to the `Interaction Profiles` list. `Meta Quest Support` can be enabled under`OpenXR Feature Groups`. `Oculus XR Plugin` can be used in case of need.

8.10 Build

To adjust the settings for application's build go to `File` and `Build Settings`. Manage which `Scenes` should be included in the build. Select a platform to built to.

9 Testing

The last chapter presents the testing using the XR Device Simulator, the HTC Vive Pro headset, and the Meta Quest 3.

9.1 XR Device Simulator testing

Playtest the application using the XR Device Simulator with mouse and keyboard. Press buttons with mouse or using the right controller. Toggle 'Y' or hold 'Space' on the keyboard to manipulate the right-hand controller. Left click with the mouse on it when the button is highlighted to simulate the trigger button. Use 'W, S, A, D + Q, E' for movement.

There is a difference between XR Device Simulator testing and testing with the headset in the limitations of area for movement. There are no limitations for movement without the headset. Due to this, there is an option to move around the whole hospital. Also, there is an option to move through walls. Of course, this is not desired. Objects behind the wall are visible to user when it happens. The visibility is desired. It is more comfortable for a person with ASD to see what is behind the wall, than to see a black screen or something similar. However, it is less likely to happen when using a headset due to the limited area for movement. When it happens, it should not bother users with ASD.

XR Device Simulator testing demonstrated in Figure 19 and Figure 20 looks promising. Some shadows are still showing Perspective aliasing. It could be possibly fixed by increasing the maximum shadow resolution. The doctor and nurse characters add realness to the VR experience. Sometimes, the looping of these captures is not perfectly smooth. It looks better in the build version with the headset.

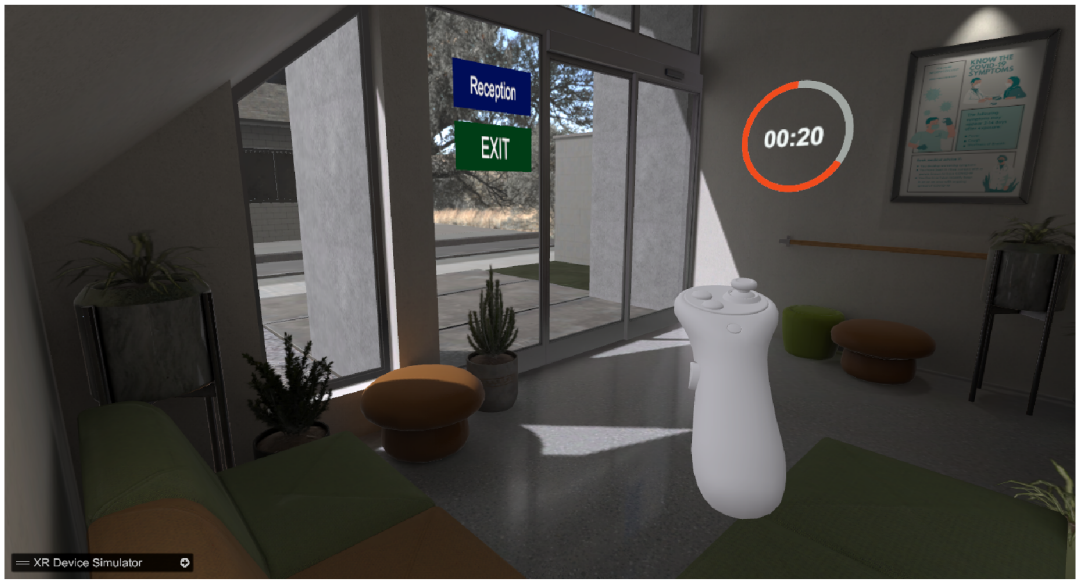

Figure 19: Waiting room

Figure 20: Dentist room

9.2 HTC Vive Pro headset testing

There was a problem with the connection to the HTC Vive Pro. After trying everything presented in Connection to HTC Vive Pro, creating a new Unity project fixed it perfectly.

Firstly, there were UI buttons only at the reception and in the dentist room. After testing it with the headset, there were two more buttons added to the waiting room, due to the size of the play area. Also, the position of teleports was adjusted due to the size of the play area. Multi-pass Render Mode was too slow. Single-pass works better with the HTC Vive Pro. Also, other optimization techniques described in Optimization were used.

Also, experts from JAN z.s. suggested other options of VR headsets, like Oculus. A lighter headset could be more suitable for users with ASD, as they tend to be more sensitive in the face and head area.

Overall, experts from JAN z.s. found the VR application user-friendly and well-suited for users with ASD. The environment is pleasing, and UI is simple and ideal. They appreciated the teleportation between rooms as it is better for the vestibular system than continuous movement.

Finally, my friend with Asperger syndrome provided positive feedback.

9.3 Meta Quest 3 headset testing

Thanks to Bc. Barbora Frýdová the VR application was tested on Meta Quest 3 headset. Optimization is still in progress.

Conclusions

In this bachelor's thesis, I designed and created a dental office environment in virtual reality in Unity for HTC Vive Pro. The dental office is situated within a hospital building, allowing for easy addition of more training scenarios. Potential additional training scenarios may include a blood sampling room. Additional animations for the dentist and nurse can be added easily according to requirements, and their appearances can be modified without difficulty. Sounds could also be added into the dental office. A more interactive and educational version would be interesting.

This project allowed me to explore new technologies, communication with clients, and more. I attended a training with JAN z.s. and visited their practice dental office. Also, I was able to use my experience as a dental assistant in creating a virtual dental office environment.

I tried to make the application user-friendly and meet the requirements.
I optimistically chose a more pleasant and modern environment for the hospital and dental office, as they are more and more frequent in reality. The objective is to show that a visit to the dental office doesn't have to be a daunting experience and can be managed.

Závěr

V této bakalářské práci jsem navrhla a vytvořila prostředí zubní ordinace ve virtuální realitě v Unity pro HTC Vive Pro. Ordinace se nachází v prostředí budovy nemocnice a tak se dají jednoduše přidat další nácvikové scénáře. Další nácvikové scénáře mohou obsahovat ordinaci na odběr krve. Doktorce a sestře se jednoduše přidají další animace podle požadavků. Bez problémů se dá i upravovat jejich vzhled. Do zubní ordinace by bylo možné přidat i zvuky. Zajímavá by byla i interaktivnější a edukativnější verze.

Tato práce mi umožnila vyzkoušet si nové technologie, komunikaci se zákazníkem a dalšími. Zúčastnila jsem se školení s JAN z.s. a navštívila jejich cvičnou ordinaci. Zároveň jsem mohla využít své zkušenosti zubní instrumentářky při vytváření prostředí zubní ordinace.

Práci jsem se snažila udělat uživatelsky přívětivou a tak, aby splňovala požadavky. Prostředí nemocnice a zubní ordinace jsem optimisticky zvolila příjemnější a modernější, stále jich je v realitě více a více. Cílem je ukázat, že návštěva zubní ordinace nemusí být děsivá zkušenost a dá se zvládnout.

A Electronic data content

`text/`
: This folder contains PDF file with the text of the thesis, created using style from Department of Computer Science UP. Including all the files needed for generating the PDF file with the text of the thesis (in a ZIP file), meaning the source code of the text, images etc.

`README.txt`
: Text file with information needed to install and run the application.

`src/`
: This folder contains all source codes of the application and all installation files.

References

[1] *JAN z.s.* 2024. Available from WWW: ⟨http://www.jan-olomouc.cz/⟩.

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