DEVELOPMENT OF IMMERSIVE EXPERIENCE FOR THE RECONSTRUCTION OF A VINTAGE CINEMA THEATRE

Explore techniques of game design and immersive technology to recreate the experience of exploring the Flamman cinema building

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ABSTRACT

Virtual reality (VR) made cinema applications today can be considered as simple media players that are often set in a fictions environment without the privilege of explorability given to the user - who from the start remains seated in the virtual world. That is due to the definition of user control which is restrained to the extent that the controllers are moderated to the definition of interaction with graphical user interfaces such as media player buttons. This effectively solves the need dedicatedly for people who expediently use VR applications analogous to media players.VR has the potentiality to offer rich sensory experience, therefore even a media player could be destined for more than the current trends with a slight addition of cultural heritage and gamification. This addition could potentially support the *simulationist* people of the GNS theory by Ron Edwards who would seek for a more immersive experience; being interested in playing the role of a visitor, having the ability to objectively explore and interact with the virtual environment that was once existent. Ideally, the simulation should have an expressly mediated representation of realism to fulfil the expectations of those people who prefer games with a high *plausibility* in the "*loyalty to world"* fader of the *Mixing Desk of Faders*, which is a game design tool where each fader covers the intensitivity of a specific design choice. This research project is dedicated to preserve the cultural heritage of the once existent Flamman cinema theatre by the virtual reconstruction of its architectural, historical and cultural correctness compositional to the Flamman experience. The level of reconstruction was conditioned on remaining photographic evidence and technologies used to develop the simulator accordingly for the target platform, Oculus Quest 2 VR system. Blender 3D content-creation suite was used for the construction of geometric elements, followed by the assemblement of those and the development of the simulator which was carried out with Unity cross-platform game engine and Oculus Integration plugin. Based on these aspects, I conducted an action research to answer the main research question regarding the determination of influential factors on quality in the reconstruction of the original Flamman experience. I began the development with the implementation of user control, with a cautious design for motion sickness; continued with development experiments for emphasizing the respected time and space while aiming for the reachment of a highly realistic physical and graphical representation of those. These were the implementation of haptic and visual elements, physics based intractable objects and inverse kinematics.

Obstructed by challenges due to technological affordances which led to the utilization of performance optimization techniques, consequently to the reduction within the graphical quality. The resulting prototypic Flamman simulator has been evaluated by participants under the conduction of play test sessions followed by interviews with the conclusion summarizes high equality in the successfully reconstructed Flamman which authentically represents its vintage cinema atmosphere. Ultimately, the closure of the thematic analysis concluded Oculus Quest 2 underperforms in graphical realism, nevertheless it is an outstandingly great system for the purpose of immersive simulations.

Keywords: virtual reality, Oculus Quest 2, preserving cultural heritage, Blender, Unity game engine, game design and development, haptics, immersive simulation, motion sickness, technological affordances, computer graphics, performance optimization, play testing and observation, interview, thematic analysis.

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1. INTRODUCTION

I proposed the conduction of an action research under the domain of game design that was carried out in an academic setting. The possible stakeholders of this project could be the Svenska Filminstitutet, Stadsbyggnadskontoret and Byggnadsvård Göteborgs Universitet. The approach involved the utilization of academic literature regarding game design and game programming techniques, moreover the experimental immersive design for virtual reality platforms. Being dedicated to deciphering what level of immersiveness is possible to reach was highly determinant by the capabilities and limitations of VR technology, ended with the delivery of an authentic virtual experience, a test material that is implemented in the form of an interactive prototype for Oculus consoles.

Virtually preserving the cultural heritage, the purpose of the project is to provide entertainment value for people who are interested in seeing a movie in a vintage cinema theatre that is no longer accessible, thereby providing them the possibility to experience the sense of time travel. A simulation that would place people back into the year of 1950, into the Flamman cinema theatre of Gothenburg. The domain of simulationism [1] and exploration nowadays are the priority aspects in the game design industry for virtual reality platforms. Virtual reality is considerably the most potential platform that offers rich sensory experience to the user [2] in which the task of the developers is to enrich the virtual experience with design elements and technological solutions that are emphasising the atmosphere of the intended space, time, and situation of a given context. The current trends within the immersive technology is to experiment ways of providing content and interaction forms to simulate the sensation of the lifelike experience [3], which is often challenging to do so. The issues of cybersickness [4] due to the wearing of head mounted displays is a known phenomenon. Motion sickness is attributable to the visually-induced perception of self-motion in which the perception is highly affected by the field of view and the viewing angle. Knowing that cybersickness could be a possible negative influential factor to the simulation, therefore, the adoption of some of the existing motion sickness reduction techniques was a necessity for the development such as the dynamic reduction of the rotation during navigation [5] and the reduction of the field of view [6]. Next to the sophisticated definition of motion and the refined audiovisual effects, I have experimented with opportunities to enrich the authentication of the cinema simulation by addressing the interaction forms and the probing of the haptic elements.

2. BACKGROUND

This project is dedicated to preserve the cultural heritage of the Flamman cinema theatre along with its cinema going experience through a VR application within a realistic simulator. The Flamman simulator which is essentially intended to be a simulation game with the feature of watching a movie and in which the user plays the role of a visitor. Next to this, the privilege should be given to the user to freely explore the 3D space with an

Oculus Quest 2 device that would virtually place the user inside the reconstructed cinema building. In this section I discuss and analyze examples that could be utilized for creating an authentic and realistic simulator game. In all examples, the analysis includes the representation of the player within the game, the graphical quality, moreover highlight elements that make their gameplay a quality experience to the user.

Based on these aspects, I begin this section with a short analysis of three games in which the plot is related to (a) historic and cultural heritage and discuss their correctness. By following that, two VR compatible video player applications are described by analyzing their allowance of interaction forms between the player and the virtual environment. As well as describing my experience while using these applications including advantages and limitations. Ultimately, I gathered information regarding the comparison of capabilities between untethered to tethered VR devices, then discussed the performance of Oculus Quest 2 which reveals the predictable technological affordances to the development of this project.

2.1) Historic and Cultural Heritage in Games

2.1.1) Sid Meier's Civilization

Sid Meier's Civilization game series [7] are turn-based strategy games where the task is to take care of the welfare of the chosen civilization by constructing, expanding borders by exploring new areas or evading other civilizations. The player may choose between defensive or offensive tactics per turn. Starting from 4000 BC, the time is lapsing and the civilizations age together. To begin, the player picks a leader of an empire from a variety of the known historical figures, moreover can choose the game speed and select the world from the map types.

Those map types are both geographically and cartographically fictive, none of them are reconstructed of the real world map. Thus the game takes place in a fictitious world where the continents are scattered differently. Historical incorrectness is also sevelry manifested in the gameplay. As an example to this, the leader who was picked is likely someone who lived much later, nevertheless, the game starts at 4000 BC. Sid Meier's Civilization disregards the migration history of the civilizations and historic events that took place, for instance, the invasion timeline of the Roman Empire, or the two world wars. Therefore the player does not get an insight into knowing who were the allied nations and who were their enemies. Instead, it becomes the player's responsibility to shape the history.

On the other hand, the representation of culture is highly mediated. The appearance of the game characters are true to the respected ethnicity and time, the historic figures are faithfully reconstructed, thus they even speak with the corresponding accent. Being a strategy game, the player does not have one protagonist avatar and the controls are animation based. Therefore, when the player clicks somewhere on the map, the figures travel over the pinpointed tile which seems to be carried out in a realistic manner. The game also features some future technology of which I cannot refute in terms of realism.

Civilization IV supports high definition graphics. However, it has some cartoonistic appearance. For instance, the clothes of the leaders are very detailed with textures, but their skin seems to be rubber-like. In-game weather or daytime lapse is not featured, however many other datiles are structured to visually engage the players. The water and construction sites are animated, as well as the people and combat events.

2.1.2) Mafia II

Mafia II [8] is an open world third-person shooter game released for Microsoft Windows, PlayStation 3, PlayStation 4, Xbox 360, Mac OS X, PlayStation and Xbox One. The game is set in between 1940-1951 in the United States consists of fictional cities based on real cities that are reconstructed in between this time period in the game. Next to the buildings, the game mediates the respected time by the appearance of the game characters, weapon models, car models, and old music played in the different radio stations. The cities are portioned to various districts that are representing the mixed race population of the United States. These districts are the wealthy suburbs, large scale industrial complexes and slums of tenement blocks inhabited by different migrant races. With the game being open world, the player has the privilege to freely explore the game world other than doing missions.

The plot is based on the cultural history of the Italian-American organized crime network across the United States and wars in between the different mafia affiliated "families" using fictitious names. The player embodies the protagonist character Vito Scaletta, who is indicatively an Italian-American person. He was sentenced to serve in the U.S. Army during World War II due to the committed criminal act of robbery, Vito joins the mafia after his terun from the war.

The gameplay is based on realism, such that the protagonist character is customizable by walking him into the clothing store and purchasing outfits of styles that are typical to the era in which the game takes place. Moreover, publicly committed criminal acts are untolerated by the police authorities, thus the game features the wanted meter which determines the level of law enforcement response. Physical realism is featured as well by the definition of physics based characteristics and the realistic damage system. For instance, collisions between vehicles result in damages. On the other hand, the game characters can fall or hit by cars, and take punches through fist fights. The level of damage is always dependent on the power of the force which may result in death. The protagonist can be healed by making him eat meals. Since the game is intended to run on powerful machines, therefore its graphical realism could be supported in high definition that can be seen in the quality of textures, lights and shadows. There are plenty of details which furthermore raises the realism such as dirt and blood, and visual effects such as the dynamic weather, smoke and fire.

2.1.3) Chernobyl VR Project

Chernobyl VR Project [9] by The Farm 51 allows the virtual exploration of the historically important ghost town of Pripyat, Ukraine, and the Chernobyl power plant area. Famous for the 1986's nuclear accident of the Soviet Union where the power plant's reactor number 4 exploded and led to the evacuation of residents within a 2,600 km^2 contaminated zone due high levels of radiation. This zone is estimated to remain radioactive for about 20,000 years, allowing only tour guided visitors to spend short visits while ensuring a great distance from the power plant, otherwise the zone is patrolled. Therefore, the Chernobyl VR Project is dedicated to provide the possibility of safe exploration, in which the user can walk around (by VR teleportation), activate 360 videos in trigger zones and listen to witness accounts by interviewees which not only gives detailed information but as well ensures the historic correctness. On the other hand, it tends to provide a faithful representation within the reconstruction of the zone by using 3D photogrammetric scans, spherical photography and 360 stereoscopic videos. Moreover, it provides realism within the graphical quality as well, therefore they put a significant effort on creating high quality shadows and texture, including details such as dirt on the glass planes of the windows.

Photogrammetry [10] is the science of capturing dimensional information of physical objects via photographic images. The technique can be used to generate geometries from 3D scanning based on camera tracking algorithms. Essentially, photogrammetry can be utilized to map single objects or entire environments by assembling a large set of photos (in both cases) taken from various angles. The quality of the generated 3D model(s) will be conditioned on the quality of photographs which requires good lighting but not too high exposure during the moment of capturement.

2.2) Video Player and Cinema VR Applications

2.2.1) YouTube VR

YouTube VR [11] is an immersive video player application that can be used to watch 180 and 360 videos in virtual reality. The compatible headsets are the Oculus Quest, Oculus Go, PlayStation VR, Lenovo Mirage Solo, Daydream View, Oculus Rift, HTC Vive, and Gear VR. Moreover, YouTube VR is supported for cardboard viewer, phone and desktop users as well.

In case of wearing one of the aforementioned VR headsets, then VR laser pointers are used to interact with graphical user interfaces, otherwise tapping or mouse clicking is accepted for the user input. The interaction is limited to the ability to browse and pick videos, and to the video player management options that are identical to the default YouTube application. The user of the YouTube VR does not have an avatar, thus s/he gets placed inside the video as an invisible viewer.

The level of immersiveness can be high in case of using one of the VR headsets or the cardboard viewer as the virtual environment becomes the selected video, and some of those are in 8K. High definition videos require strong WiFi connection, otherwise those will be laggy which breaks the immersion and makes the user motion sick as a consequence. Due to the fact that YouTube VR is a video player, therefore the user is not in control of motion other than turning the head to look around. Thus, the user embodies the camera that was used to record the video from a particular distance.

2.2.2) Bigscreen

Bigscreen [12] is a VR application where people can hangout in virtual reality, supported for users of Oculus Quest, Oculus Rift S, Steam VR, Valve Index, HTC Vive and Windows Mixed Reality. The scenes of Bigscreen are fictional environments that take place in the modern days. Mediating the sensation of togetherness that is combined with the sensation of being in a cinema together which is a truly functioning event that requires real ticket purchasement if the user wishes to use the theatre feature and rent a movie. Bigscreen features the following options: (1) rent and watch movies in a virtual cinema, (2) use it as a video player to watch locally stored video files with friends, (3) watch tv and live streams, (4) attend live events such as SpaceX rocket launches, (5) use the 4-person meeting room to split the screen and play games, (6) host a meeting, share the desktop and draw in air.

The application supports 12 participants at a time which is more than enough to hang out with friends, however this number is considerably inadequate when visiting the theatre room. Graphical implementation is quite simple, uses color textures only which makes the environment look somewhat unrealistic except for the videos which appear to be supported in HD. Users can embody 3D avatars that are customizable with pre-made parts, therefore they are given the privilege to express their ethnicity or roleplay a character of their preference. The textural appearance of these avatars are similar to the Nintendo Wii's, and being molecular just as the Rayman game character. Meaning that the Bigscreen avatars consist of the upper body only (head, torso and hands) but no joints, and they are floating in air due to not having legs at all.

Distance grabbing is used for the interaction by the VR laser pointer, thereby the user can pick up the marker pen and start drawing in the air, consume snacks, and generally interact with the graphical user interfaces. Other than seeing other people's avatars, the social interaction form of voice chat is supported. A misbehaving user can be muted by pointing at the aforementioned avatar. This action brings up the menu to block receiving the audio from that player.

2.3) Performance of VR headsets

2.3.1) Tethered vs Untethered VR headsets

From the aspect of convincingly good VR gaming, tethered headsets are considerably better in performance compared to the untethered ones since tethered headsets are connected to a computer, therefore, much of the computations which otherwise require high processing power can be done on the computer instead of the headset. However, this creates a reliance on the computer's power when it comes to the game development, which can be yet determinant for the provision of quality. The processor of cheaper computers are incapable of handling high graphics therefore images may be pixelated and the performance could be laggy. Moreover, tethered headsets bring up accessibility issues regarding the fact that the user must be attached to the computer, which means s/he must have access to a computer device and will have limited mobility due to the wires. Contrary to this, tethered headsets allows the user to walk around in the physical space by the use of external sensors such as the laser tracking stations in case of HTC Vive, while untethered devices limit the players to remain stationary at position, allowing them to look around in 360° at most. Yet, tethered has other accessibility issues since the feature of walking around while playing requires the user to prepare for the game, meaning that the user needs to find a room that is large enough and clear it from furnitures that could be obstructing the play area. Oculus Quest 2 is an untethered device which resolves the accessibility issues of mounting the player to the computer, yet features the possibility to move around in the physical space, however the play area will be limited to the boundaries of the guardian. Preparation task of the user is to set up the guardian including the alignment of the virtual floor to the physical one and to draw the radius of the intended play area. The player can walk within this guardian which is tracked by the inbuilt 6DOF sensors of the Oculus headset.

2.3.2) Oculus Quest 2

My hypothesis regarding the authenticity of the reconstructed Flamman experience is that its resulting quality is highly determinant by the technological affordances of the development environment of Unity, complexed with the incorporation of compatible solutions dedicated for the target platform, Oculus Quest 2, which I selected mostly for the reason mentioned above. VR headsets in terms of performance can be compared to high-end smartphones, yet are significantly distinguishable from the experience that PCs and consoles can provide. The latter ones are known to be high electricity consumers, requiring power sockets and have cooling systems, Oculus Quest 2 has a USB chargeable internal battery with the capacity of storing 3.640mAh that lasts for about 2-3 hours in playtime, and a miniature fan that cools its Qualcomm Snapdragon XR2 coprocessor platform. Asserted by the comparison [13], the CPU of Oculus Quest 2 performed worse compared to the earlier releases, however its GPU performance is finer than the rest, and is similar to the performance of XBox One. During the discussion at the annual developer conference in 2018, Oculus Connect 5 [14], it was stated that the rendering of textures constitutes one of the highest threats for the CPU of Oculus, thereby those are recommended to be compressed with Adaptable Scalable Texture Compression (ASTC) method in order to optimize for performance and power consumption. ASTC works in two stages on a high level. First, the algorithm divides the image into fixed-size blocks of texels, and then compresses those texels into a fixed number of output bits. Then in the second stage, it calculates the gradient color values of each texel, and each block stores the end-point color for the gradient and an interpolation weight for each texel. The benefits of using ASTC on Oculus is that the textures are converted to format that are designed to be read fast on GPU and use little bandwidth, as well as occupying small space on RAM. Compared to other compression methods, ASTC offers more options to developers to fine-grain the quality of the compression. It allows the users to easily achieve balance among performance, visualisation and power consumption. In addition to this, the assertion was also made that Oculus is capable of running a game smoothly if its frame rate does not drop below 74 frames per second (FPS).

3. PROJECT AIM

The problem is that (many) closed down cinema theaters cannot be experienced anymore. However with the VR technology, the possibility is given to recreate the cinema room and partially recreate the experience of going to see a movie in that particular cinema theater.

Nevertheless, the currently available virtual reality cinema applications are focused on the young target group as they are considered to have access to VR headsets [15]. Adjusted to their needs, the visualization and aesthetics of those cinema simulations are focused on providing the experience of being in modern, futuristic, and in fictions environments. However, different target groups may be seeking for the experience of time traveling back into the past, and virtually explore the once existent and historic cinema theaters that are now no longer accessible to the public. Utilizing the photographic documentation, I proposed the virtual reconstruction of the Flamman cinema theatre building of Gothenburg along with the recreation of the atmosphere that is set in the decade of the 50's. Secondary goal was to provide engagement to the users by enriching the simulation with highly plausible loyalty to the game world with immersive design and the implementation of haptic elements. Thereby, the players would be able to fully explore the interior, purchase tickets from the cashier booth and sit into the auditorium room for a movie.

3.1) Objectives

The main goal was to create a proof-of-concept digital reconstruction of the Flamman cinema experience for Oculus Quest 2 headset by using Blender modeling software and Unity game engine.

Sub-goal 1: Accurate reconstruction of the building's interior.
Sub-goal 2: Possibility to watch a movie on the big screen using a locally stored video file
Sub-goal 3: The experience should include the lobby outside the auditorium room.
Sub-goal 4: Creation of an immersive simulation and realistic induction of haptics.

3.2) Research Questions

RQ: *What are the influential factors on quality in the reconstruction of the Flamman experience?*

- ***Sub RQ:*** *What design elements are relevant to create a highly plausible simulation of a particular time and space?*
- ***Sub RQ****: What is the resulting satisfactory level regarding the overall simulator, and why?*

In order to revive the cinema, previously proposed, there were problems to be solved. The first one is the faithful recomposition of the Flamman building which is a considerably time consuming process requiring preliminary research of the characteristics of the building and the aesthetics of 1950. Obtaining this information requires investigation of the remaining evidence in order to determine the right type of elements that are culturally and historically correct to this space and time, that to be followed by the 3D modeling work.

The second one is the experimentation regarding what implementation choices to make upon the simulator during the development with Unity, which - as a matter of fact - an application intended to be running smoothly on Oculus Quest 2. These implementation choices can be subcategorized into: (1) the incorporation of modern elements such as inclusive design, without harming both the aesthetics of vintageness and realism; (2) the creation of the highest possible resolution for the realistic representation of the real world while ensuring the performance; and (3) cautious design to reduce motion sickness. These aspects consequently determine the reconstructable elements, just as their quality, subsequently affecting the preservation of the cultural heritage in the Flamman experience.

Therefore the third problem to be solved is how to limit the sacrifices due to the technological affordances and performance optimization in a way that the simulator is still capable of mediating the time and space in a plausible manner that is identical to the original experience.

3.3) Expected Results

Create a functioning and realistic VR prototype of the Flamman building that is reconstructed using Blender 3D modeling software and Unity game engine. This project was aiming for achieving the learning outcomes stated at [16], by the contribution of a unique application which provides the simulation of a vintage experience for the modern VR technology. To do so, the combination of academic theories together with modern technologies was the approach to the problem of the creation of an experimental prototype that serves as a proof of concept.

4. THEORY

This project has four theoretical pillars. On the one hand there are the game design theories that concern the user experience. Secondly, virtual conservation for cultural heritage. Thirdly, the motion sickness theory in virtual reality, and finally, the area of computer science that facilitates the development of experiences with technology.

4.1) Game Design Theories

4.1.1) Technology-Driven Experimental Game Design

Since the artifact of this project is an interactive product intended for the target platform determined to be the VR system, Oculus Quest 2, therefore its conceptualization is subjective to technology-driven experimental gameplay design [17] principles. Technology-driven as the initiation of design is specific for a technology, Oculus, complexed with the development to be established on Unity game engine as an additional technological artifact. Consequently, design choices must be under the consideration of feasibility specific for these technologies; meaning the complete familiarization of capabilities and limitations by the induction of preliminary research such as regarding requirements and specifications prior to the design process; obligately keeping those in mind throughout the entire production process. On the other hand, this project is experimental to the fact concerning the shifting of an existing physical environment to virtual reality, emphasizing the digitization of vintage aesthetics that comes along with it; ideally both without causing any sort of disortment to their authenticity. The reconstruction requires creativity since it aims for the creation of an immersive way of exploring the reconstructed environment of Flamman, possibly with the necessity to fusify some level of modernism with audiovisual goal indicators and UI elements as a predilection for intuitive design [18] in order to support the modern VR user who subconsciously expects consistency.

4.1.2) Game Design Concepts (MDA, RPG, GNS)

According to Martinez [19], the design of a game with VR is a complicated process since developers must have two clear points of view: the technical point of view and the design point of view, since it must be programmed on non-standard equipment (Oculus for example) for users to experience a multimodal interaction and also the user experience design must start from scratch. However, looking at the interactive product as a game, we can see the game in VR as a description of the MDA model. Hiruke proposes the division of the gaming experience in three dimensions: mechanical, dynamic and aesthetic [20]. That said, the problem pointed out by Martinez can be seen as a preliminary analysis of the MDA model. Furthermore, the problem pointed out by Martinez could be mitigated by pointing to the experience as a role-playing game (RPG), since Edwards proposes a way to design and analyze a game according to the gameplay of each player, this scheme is called GNS [1]. This terminology is built around RPGs to help in the categorization of their gameplay type, as to find which characteristics are driving the game mechanism: *gamism*, *narrativism*, and *simulationism*.

Gamism	*Narrativism*	*Simulationism*
competition between players, combat in game (winning and losing), where the strategy is important.	Character creation and playing the role in the story, conflicts are narrative, plot/setting/emotions are important.	Exploration is important for a simulationist, emulation of a reality/fiction, experience is important.

Table 1. GNS Terminology: Modes of RPGs [1]

4.1.3) Mixing Desk of Faders (MDF)

The *Mixing Desk of Faders (MDF)* by Stenros et al. [21] is a game design tool for defining the intensity of player experiences of, inter alia, freedom, customizability, pressure, cultural expression and many more. The mixer has the appearance of an equalizer that can be interpreted as an "equalizer" of the overall game design characteristics determinable by the 12 faders adjustments. Some faders make good combinations together, some of them are independent of each other, and some of them should not be combined with extreme domination or vice versa. Here I would like to highlight the "*Loyalty to World"* fader which can be set between p*lausibility* and *playability.* High dominance of *plausibility* in a game design means that the game or roleplay is true to the facts based on chronology; or in other words, the historical and cultural correctness that prohibits having fictitious elements or unrealistic physical behaviour for game objects, non player characters, neither for the protagonist. Contrary to this, *playability* dominance ignores realism. Instead, it is used for the reason to please the audience or players in a way that it features the aesthetic of "fun", in which the gameplay or simulation could be fictitious and unrealistic by the provision of fictitious world elements and special movement abilities. Regarding this, another fader called *"Environment"* becomes relevant here which can be set in between *360 illusion* and *material independence*. The 360 illusional environment is when the dependency of physics and senses applies in the game as in real life, including realistic behavioural expectations. Moving this fader to the minimum (material independence) weakens this dependency and can result in a completely fictitious environment. Therefore, the *Loyalty to World* and the *Environment* faders could be powerful from the aspect that their level setting will highly affect the resulting aesthetics for those people that Edwards [1] considers being interested in the *narrative* and *simulationist mode*, rather than in the *gamist mode* of a game.

By the means of emphasis that should be laid on realism of a VR platformer, several techniques [22] address the induction of supplementary audiovisual effects as an enchantment for the authentic mediation of a cultural heritage. Based on the prescription of vision and hearing, the "EvoluSon" [23] project for instance creates a coherently interactive visual and aural environment with the use of musical tracks that are representations of periods over the history. Considering the plausibility, the Flamman cinema simulation therefore must be reconstructed realistically, moreover should include audiovisual elements representing the vintage era to convince the user by his/her perception via this immersive design. Other than watching films, the exploration of the lobby area for instance could be enriched by seeing old movie posters and hearing of the crowd and fading music tracks of the 1950's.

4.1.4) Dark Patterns Theory

Dark patterns [24] are intentionally implemented structures within the game design which could be described as using marketing driven tactics that are intentionally structured by the game creators to increase their income and expand their revenue streams. Players likely will experience grinding, the feeling of wasting their time while unaware of being manipulated to obtain the rising urge to make purchases as they seem to be unable to pass levels or particular obstructions due to the induction of AI players, fake scoreboard, encouraged return visits and time-pressure. Meanwhile the audiovisuals are intensively advertising the "solutions", thereby manipulating the players what should be their personal goals, however, those come with the costs of spending money and / or the requisition of the player's connections via social media that are often linked to dark patterned games.

Temporal Dark Patterns	***Monetary Dark Patterns***	***Social Capital-Based Dark Patterns***
Grinding *Playing by Appointment*	*Pay to Skip* *Pre-Delivered Content* *Monetized Rivalries*	*Social Pyramid Schemes* *Impersonation*

Table 2. Types of Dark Patterns [24]

Other than the personality, toleration due to compensation via efficient and exciting game design solutions is more likely the other reason why players yet do not give up playing the "infected" games. Hence, the randomness, social interaction and combat related design patterns together with the player-prestige set faders are there to make players addicted (ideally). However, that is probably only in the case when the intensitivity of dark patterns is minimal, less frequent or somehow yet balanced compared to the "good" design solutions.

Good solutions are design structures in games (mechanism, dynamics and aesthetics with the combination of various pattern types) that are driving the game progression and influences the players both positively and negatively. The planned negativity injections leads to a stronger sense of achievement / social interaction and engagement to the game. Thus the "good" design patterns [25] that are structured in games together with the game's GNS scale [1] formulates the main areas of combat & handling death, and influences the progression. The enrichment of engagement also compensates the players to tolerate dark patterns. Relevant to think about dark patterns that could be manifested in a cinema simulator as well. For instance, the *pay to skip* for an upgraded user account if ads are showing in the video player, or having to pay in order to watch a movie. Depending on how realistic the simulator is, *grinding* and *playing by appointment* could be unintentionally structured such as having scheduled movies, thereby the user must wait for the time of the event, moreover grinding due to having to stand in line when buying a movie ticket in the virtual environment.

4.2) Digitalization of Cultural Heritage Theory

Since the project tries to preserve an old building and its function, the understanding of heritage digitization processes is necessary. Given that the ultimate goal is the digital preservation of the film theater as a digital heritage, existing works that encompass processes for conservation through conversion to digital heritage are taken into account.

As Santana Quintero [26] says, for the digitization of architecture, the heritage values, integrity of the site, public awareness and the interpretation that the site is going to be taken into account to show it virtually and possibly consider it virtual heritage. These qualities in this case would be the digital preservation of Swedish architecture so that future generations of Gothenburg residents remember the legacy of Flamman's cinema and also that these generations understand the difference between current architecture and that of the middle of the century XX.

Likewise, Adisson [27] points out that the digital reconstruction process benefits from the digital documentation of heritage, such as photographs, maps and field documentation, which in turn, according to Satana Quintero, must be filtered to understand what and how it should be digitized. Which for our case means building digitally in 3D modeling and texturing tools like Blender. However, as Lassandro [28] points out, once the investigations of the historical documents are done, the artifacts must be identified and reproduced in three dimensions with their respective scenarios to reproduce them in a more realistic way in the modeling tools, that is, to identify how light affects the colors of artifacts and how the scene should look in its respective era.

4.3) Cybersickness Theory

Joseph J. LaViola [4] derives the sense of self motion and the sense of balance as the main causal factors to the tendency of cybersickness in virtual environments. His work reveals various cybersickness symptoms, inter alia, *(1) eye strain, (2) headache, (3) pallor, (4) sweating, (5) dryness of mouth, (6) fullness of stomach, (7) disorientation, (8) vertigo, (9) ataxia, (10) nausea, (11) vomiting*. These symptoms have been proven to be caused by the user's vestibular system (sense of balance) in relation to the sensation of motion affected by two main chatgerocial factors (table 3), the *display and technology issues*, and the *individual factors*. Ultimately, he proposed four reduction techniques in order to reduce cybersickness (table 3) dedicatedly to the connection of the vestibular and visual stimuli.

Display and Technology Issues	
Position tracking error	Position tracking error of the head and limbs could cause the jitter effect in VE, giving an uncomfortable view to the user who may experience symptoms of dizziness and lack of concentration. *"Position trackers are not one hundred percent accurate and depending how inaccurate they are will determine if they will cause cybersickness symptoms. These tracking devices also have a tendency to report slightly unstable information which will cause jitter."*
Lag	Delayed motion due to lag causes cybersickness symptoms such as in the case when the user waits for images to be updated which may appear at the expected places. *"Lag represents the time between the user initiating an action and the action actually occurring in the VE. A very common case of lag in VEs is the time it takes to send information from a head tracker to the computer, have the computer process the information, and then update the visual display."*
Flicker	Flicker effect happens when the refresh rate is below 30Hz which could cause eye fatigue between individuals who tolerate the ongoing flicker fusion frequency threshold differently, likely through a wider field of view within the VE. *"One of the goals of virtual reality is to surround the user's field of view with visual stimulation. This goal represents a problem since the wider the field of view the more susceptible humans are to flicker. In order to reduce the possibility of flicker, the refresh rate of the system must be increased."*
Individual Factors	
Gender	Females are more tendentious to experience cybersickness symptoms due to their characteristics of having a wider field of view compared to males. The wide field of view is considered to increase the likelihood of the flicker as mentioned above. *"As it turns out, women appear to be more susceptible to cybersickness than men[1]. One of the reasons for this is that women generally have wider fields of view than men."*

Age	Youngsters are more inclined to experience cybersickness symptoms which slowly decrease after reaching adulthood. *"Cybersickness susceptibility is the greatest between the ages of 2 and 12 years of age. It decreases rapidly from 12 to 21 years and the more slowly thereafter. They claim that around 50 years of age, cybersickness is almost nonexistent."*
Illness	Illness is considered to be a contributing factor for the tendency of cybersickness, therefore the use of VE simulators is not recommended to this group. *"Someone who is suffering from illness, fatigue, sleep loss, hangover, upset stomach, periods of emotional stress, head colds, flu, ear infection, or upper respiratory illness should avoid using VE simulators."*
Position in the simulator	Virtual environments which require the user to perform postural controls while standing could increase the tendency of cybersickness compared to the scenario where the user remains seated while playing. As well as for a controller-passive participant in a multiplayer VE. *"Based on the postural instability theory \cite{riccio1}, sitting appears to be the better position in which to reduce cybersickness symptoms since it would reduce the demands on postural control...User's who control the simulation are less susceptible to cybersickness than those who are passive participants[20]. This phenomena is analogous to someone who gets car sick as a passenger but does not get sick as the driver."*

Table 3. Contributing Factors of Cybersickness in Virtual Environments
(Source: Summary of factors gathered from Joseph J. LaViola [4])

Method	**Application**
1. Motion Platform	Connect the vestibular and visual systems by adding a motion platform to the virtual environment simulator which should be perfectly aligned to the visual stimuli.
2. Direct Vestibular Simulation	Mount the user with a device that sends electrical signals to the *"8th cranial nerve which tricks the vestibular system into believing that there is linear or angular acceleration and deceleration taking place[4]."* - [4]. Joseph J. warns about the issue that it must be precisely timed to the visual stimuli just as in the case of using a motion platform, ultimately stating that the determination of the proper amount of electrical current is unknown.
3. Rest Frames	Discrepancies (conflicting rest frames) burdens the user's spatial perception and judgement of stationary and dynamic elements in VE. *"The concept of rest frames is based on the observation that humans have a strong perception for things that are stationary[26]. Therefore, a rest frame is simply the particular frame which a given observer takes to be stationary...The nervous system has access to many rest frames. Under normal conditions, one of these is selected by the nervous system*

	as the comparator for spatial judgments. In some cases, the nervous system is not able to select a single rest frame". To overcome this issue, the rest frame experiment was carried out which was the implementation of an independent visual background with inertial cues. As a result, cybersickness symptoms were reduced.
4. Adaptation	As an adaptation program, make users get used to the virtual environment by gradually increasing their exposure time within the simulator. However, after effects (cybersickness) may be caused due to the elongated duration of being in the simulation.

Table 4. Cybersickness Reduction Methods
(Source: Summary of methods gathered from Joseph J. LaViola [4])

Other reduction methods are proposed by Kemeny, A. et. al. [5] which attributes cybersickness to the definition of motion that is created by design choices in relation to the particular VR platform. One is the design choice regarding the amount of field of view (FOV) reduction which is suggested to limit the visual stimuli to the benefit of prescription and balance, however, with a great emphasis to be put on the level of reduction. An overly narrow display would make the objects look much larger than in real life, thereby reducing the level of immersion which causes misinterpretation and discomfort to the user in the perception of self position. On the other hand, the designer should aim for a realistic graphical implementation with the use of visual effects such as proper luminosity and blur effect that could help in the perception of distance. Secondarily, the definition of motion should be designed in a way that it reduces the continuous displacement of the user that could be made by the teleportation feature for instance.

Fernandes, A. S. et. al. [6] also relates to the vestibular system's misinterpretations due to the FOV definition in case stationary user controls (move with controllers) are defined within the virtual environment. Their work puts the same emphasis on the need of the FOV reduction and on the complexity regarding the determination of the right amount of reduction that does not expconfuse the user's self presence. To overcome this issue, they created a real-time dynamic FOV modification which dynamically changes the field of view in response to virtual motion. Essentially, it works by decreasing the FOV when the user moves virtually and gradually restoring it when the user stops. To do so, the soft edge cutouts (vignette) effect is used which limits distractions and sets the eye focus to the middle. Ultimately, this controls the FOV by scaling a variable transparency polygon inserted in front of each of the user's eyes. These polygons are referred to as FOV restrictors.

Figure 1. Dynamic FOV Reduction [6]
(Source: Screenshots from the video published by Columbia Engineering, URL: https://www.youtube.com/watch?v=lHzCmfuJYa4)

4.4) Computer Science Theory

4.4.1) Programming Principles

The resulting game performance has a main dependency on the quality of the code implementation which requires high competency of the game developer. As a negative influential factor, the aim should be to avoid making multiplicative complexity [29] and to raise the quality by eliminating anti-patterns, also known as "*code smells*" in software systems such as complex class, large class, spaghetti code for instance. In my bachelor's thesis work regarding the detection of anti-patterns I mentioned the two concepts, coupling and cohesion: *"coupling is the measurement of relative interdependence between classes as one is associated with another class, while cohesion is regarding the strength of attributes as how those are linked inside a class. If the coupling is high, and the cohesion is low, then it is considered as a non-optimal, highly complex OO design. In parallel to design patterns, the existence of anti-patterns ("code smells") are notorious for being their undesirable contradictions meaning that anti-patterns are the "collections" of consequential poor solutions to problems of frequent-occurrence"*- [30].

This non-optimal object-oriented design can be translated to the non-optimal game engine architecture when building 3D games using C# in Unity [31]. The factor of success is the efficient implementation of the game loop within the properly structured game engine architecture [32], and the continuous refactoring when possible in order to eliminate anti-patterns, the spaghetti code most commonly[33]. To do so, the game developer should follow the applicable guidelines of game programming patterns [34], inter alia, the decoupling patterns to define components and event queues; the writing of effective and unwasteful algorithms by following utilizing practices of sequencing patterns when defining the game loop, and most importantly the update method in each of the scripts; moreover the utilization of the optimization patterns regarding the data locality and object pooling that is crucial in case of working with mass amount of objects to be rendered.

4.4.2) Performance Optimization

Other than following the programming guidelines, the game developer should be familiar with computer graphics theory [35] to understand how the computational process of working with shaders, texturing geometries, raytracing, spatial data structures, defining the collision detection (discrete or continuous), shadows and reflections, and real-time rendering; all of which are the causes of severe performance cost in case of inefficient implementation. As a consequence, insufficient implementation leads to the severe increase of draw calls to the CPU, thereby to low frame rate. The bottleneck of the problem is the number of draw calls which have to be processed by the CPU before being sent to the GPU. If there are too many draw calls, the processing might take significantly longer which results in an undesired frame rate.

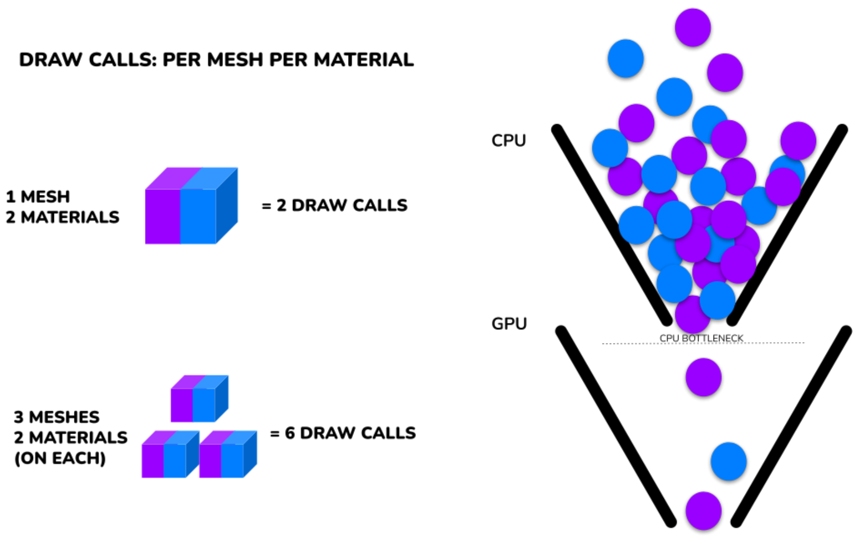

Figure 2. Draw Calls

Draw calls are created per each mesh with a material. Additional calls are created for each material on the mesh. Multiple dynamic lights also increase the number of draw calls.

General rules of thumb to restrain the number of draw calls in Unity:

- Prepare the meshes for Unity by combining them together in the modeling software. However, this will only save performance for those meshes that share the same material.
- Reduce the number of materials if feasible for reducing batches.
- Static batching objects by marking them static in Unity which will combine different objects together into a single mesh before being sent to the GPU. However this technique works on objects with the same material and could be done on those objects that will not move.
- GPU instancing can be done for dynamic objects that share the same mesh and the same material. GPU instancing can be enabled in the properties of the material.

Nevertheless, following the sufficient implementation techniques may not be enough alone. Unity game engine provides in-built tools for CPU / GPU performance optimization [36]. These optimizations techniques are addressing the number of polygons per geometric objects, the texture quality and compression methods, generating lightmaps instead of the use of real-time lights and the definition of occlusion culling regarding the rendering of those objects only that are in the camera's view frustum.

Bake Lightmap	Select all the object types `<Light>` and in the inspector window change their mode to "Baked". Then in the Lighting tab, create new lighting settings and press "Generate". This will bake the lighting data on static objects in the scene.
LOD Groups	Create meshes with decimated polygon versions and enumerate them by the following IDs: LOD0, LOD1,LOD2, and LOD3. Export these objects in this hierarchy as a single FBX file. Unity will automatically create the LOD Group component with a pre-set camera distance to trigger each LOD type which can be changed in the properties window. This will make close objects to the camera to be rendered in higher detail compared to the distant objects.
Occlusion Culling	In the inspector window, set every object whose visibility should be toggled by marking them "Occluder Static" or "Occludee Static", then in the Occlusion tab press "Bake". This will make objects to be dynamically excluded from the rendering when being out of the camera's frustum or being hidden by another object.

Table 5. Performance Optimization Techniques in Unity

4.4.3) Forward and Inverse Kinematics

4.4.3.A) Kinematic Chain

The concepts of forward kinematics (FK) and inverse kinematics (IK) [37] are based on the mathematical process used for the computation of joint parameters within a kinematic chain [38], commonly used in robotics and for creating animations on skeletal (rigged) characters. Taking an industrial robot arm as an example, the usage of FK is the finding of the position and orientation of the tool point from the joint angles. Contrary to this, the definition of IK is the finding of joint angles to set a particular position and orientation of the tool point.

Kinematic Chain [38]

"If the position and orientation of the end-effector with respect to the inertia frame are

$o^0_{n'}\ R^0_n$

Then the position and orientation of the end-effector in inertia frame are given by homogeneous transformation"

$$T^o_n = A_1(q_2)\ldots A_{n-1}(q_{n-1})A_n(q_n) = \begin{bmatrix} R^0_n & o^0_n \\ 0 & 1 \end{bmatrix}$$

$$\text{with} \quad A_i(q_i) = \begin{bmatrix} R_i^{i-1} & o_i^{i-1} \\ 0 & 1 \end{bmatrix}$$

$$\implies T_j^i = A_{i+1}A_{i+2}\ldots A_{j-1}A_j = \begin{bmatrix} R_j^i & o_j^i \\ 0 & 1 \end{bmatrix}$$

$$\text{with} \quad R_j^i = R_{j+1}^i \ldots R_j^{j-1}, \quad o_j^i = o_{j-1}^i + R_{j-1}^i o_{j-1}^j$$

4.4.3.B) Forward Kinematics (FK)

Usually, forward kinematics is the default way of defining the relationship of bones on an avatar rig. For instance in Blender, the user can select from pre-made armatures of types: *Human (Basic)*, *Human (Meta-Rig)*, *Animal*, *Single Bone*. Other than the latter one, all armature types are defined with the FK kinematic chain automatically. In FK, the transformation of bones only influences bones that are further forward down the chain of bones. When any bone chain is rigged with FK, it means that the bones are chained from parents to children. This creates arc movements by default, for example, if a parent bone is rotated, then all the children bones rotate along in an arc movement.

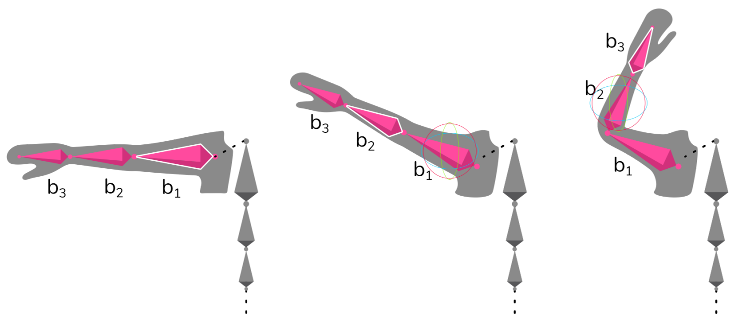

Figure 3. Animating FK Hierarchy Chain

In this case, this arm position requires the individual transformation of bones manually.

Dependency of bones: $b_3 \rightarrow b_2 \rightarrow b_1$

$\textit{where } b_3 = \textit{hand bone}, \; b_2 = \textit{forearm bone}, \; b_1 = \textit{upper arm bone}$

4.4.3.C) Inverse Kinematics (IK)

IK considerably is an excellent feature to use in games applied for the protagonist game character which could potentially raise the level of immersiveness when the user controls or embodies one. Inverse kinematics works the opposite as FK. Instead of influencing bones forward down the chain, IK allows for the transformation of a bone near the end of the chain to influence bones that are further up in the chain of bones. Meaning that, a child bone has influence over the parent bone. The animation of every bone of the chain separately becomes obsolete, instead the whole chain can be animated only by the end effector. For instance, if the hand bone is moved upwards, the upper arm and forearm bones will automatically determine where they have to be to accomplish that movement. Important to note that with IK, joints move in line trajectories, therefore the arc degrees per joint should be defined in order to create natural movements and avoid the collapsing of joints.

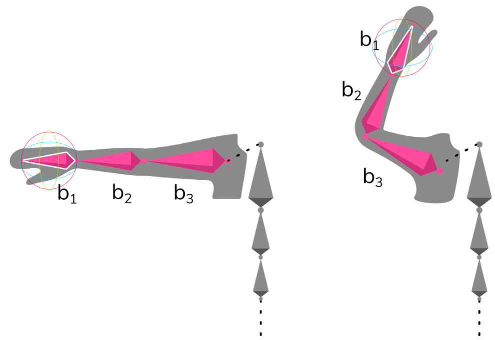

Figure 4. Animating IK Hierarchy Chain

In this case, this arm position can be reached by the transformation of the effector bone, the rest computes the appropriate position and rotation.

Dependency of bones: $b_1 \leftarrow (b_2 \leftarrow b_3)$

$$where\ b_1 = hand\ bone\ (effector),\ b_2 = forearm\ bone,\ b_3 = upper\ arm\ bone$$

According to this user manual [39], IK is supported in Unity for humanoid character rigs which prerequisites having the avatar model correctly configured of mapped body parts and muscles. Currently, IK feature is unsupported for the other rig generation types “legacy” and “generic”. If the avatar was rigged correctly during its modeling phase in an external software, then its configuration will be automatically and correctly mapped in Unity which does not require furthermore steps in the preparation of the avatar. The next step is the creation of an `Animator Controller` with at least one animation in the state machine and mark the layer(s) with the “IK Pass”. Additionally, a script should created and be attached to the `Animator Controller` component in which the desired IK behavior shall address the `Animator` using the provided functions:

```
public void SetIKPositionWeight(AvatarIKGoal goal, float value);
public void SetIKRotationWeight(AvatarIKGoal goal, float value);
public void SetIKPosition(AvatarIKGoal goal, Vector3 goalPosition);
public void SetIKRotation(AvatarIKGoal goal, Quaternion goalRotation);
public void SetLookAtPosition(Vector3 lookAtPosition);
public Vector3 bodyPosition;
public Quaternion bodyRotation;
```

5. RESEARCH METHODOLOGY

5.1) Research Setting

This project is conducted under an academic setting within the Department of Computer Science and Engineering, Game Design and Technology MSc program of Gothenburg University. The potential stakeholders of this project could be the Svenska Filminstitutet, Stadsbyggnadskontoret and Byggnadsvård Göteborgs Universitet. Flamman theatre was opened in the year of 1935 and functioned as a cinema theatre till 1982. Today, it is home to the Finnish Helluntaikirkko Pentecostal Church. Culturally important, since it was the first cinema theatre in the city that was designated to sound films. Its unique architecture was considered very modern at that time with its large glass hall, 28 meter tall salon that is slightly wedge-shaped, sloped floor and 684 seats facing towards a large canvas. The sides of the proscenium used to be decorated with allegorical paintings of Greek mythological gods. Today the building is architecturally intact, however the proscenium area has been replaced with a preaching stand and with significantly reduced amount of seatings, moreover the engine room has been emptied and currently functioning as an office space. Beforehand, the Flamman building has been documented in the forms of small-scale blueprint drawings and photographs of which source materials were utilized during the virtual reconstruction of the cinema.

5.2) Research Strategy

The research strategy utilized the methodology of action research applied in an experimental nature, meaning the experimented tools used in the game development before succeeded in the creation of a working prototype which not only preserved the cultural heritage in an authentic way, but as well has an engagement value next to that. The reason behind the selection of action research is due to that this methodology seems to be the most rational choice suitable for the purpose as it is, inter alia, participative, context-based, and allows the development of an artifact based on participants' reflections and the finding of some of conclusive evidence at the point of its application - according to Koshy et al. [40]. This method is usually applied throughout its five phases: *(1) diagnosing*, *(2) action planning*, *(3) taking action*, *(4) evaluating*, *(5) specifying learning outcomes*. Therefore, I considere action research as a perfect fit for this type of project since it seems to advocate the agile mindset; thus it is combinable with both the agile software development processes and the user centric aspect within game design in general, which is the induction of prototyping and play testing sessions for instance.

In order to answer the research questions, qualitative data gathering and thematic analysis was applied with the combination of experimental results compared to the academic literature review. Therefore the answers could be formulated from deep analysis regarding the experience of aesthetics together with the study of the literatures and from the play test and interview results. The planned working process:

- ***Determination of Technology:*** My choice of game engine was Unity because I prefer this tool over building my own game engine since the definition of shaders and buffers from scratch would be a very time consuming process. Unity has a considerably user-friendly layout which allows the developer to build games rapidly while being able to organize and define relationships of the implementation on a high abstraction layer rather than on the code level only. Thus, it becomes obsolete to define shaders and buffers with code implementation, however the privilege of scripting those is always possible. Unity provides a high transparency of the entire architectural hierarchy. Moreover, it features real-time development meaning that changes are supported while the game is running (in "play" mode), which can be either preserved or automatically reverted based on how pleasing the result is. This aspect gives space for quick tests and supports the rapid determination of the right values to be assigned to the variables. My selection choice regarding Blender modeling software is due to my competency in working with it. I have years of experience in creating custom contents and assets for games, often for making rigged humanoids, animations and objects. Blender is not easy to learn, however, it is commonly used for creating assets for Unity since its compatibility of importing data seems to be well supported, thus the data conversion of Blender files does not lose detail. On the other hand, Blender is a great tool for building geometries from scratch in which the full control of each vertex is given to the designer. Such an aspect is important when it comes to building meshes and importing those in games as the polygon count should not be too high, otherwise it could become a menace to the game performance.
- ***Preliminary Research & Project Setup:*** Preliminary research was performed by my academic supervisor who had benchmarked existing VR cinema applications and formulated this master thesis project suggestion regarding the virtual reconstruction of Flamman, moreover he had gathered photographic references and copies of the original blueprints. I began the research by studying these inherited architectural blueprints and pictures of the Flamman cinema that was meant to be reconstructed virtually. As well as researching the decade of 1950 and aesthetics specific to Sweden, Gothenburg of this time. In parallel to this, it was necessary to find out which frameworks are compatible that can be used for the development of the prototype in the chosen game engine, Unity. The plan was to develop the application for Oculus Quest 2 headset, therefore the setup of the Unity project required the installment of the Oculus Integration and XR plugin tools. The further setup of these tools has requirements specifications, an online documentation guide regarding the appropriate project settings that determines the upper limit of the quality and performance. After the setup of the prototyping environment, the next step was the creation of a version control repository and sync Unity with GitHub. The ideation process for designing the cinema aesthetics I utilized the learning outcomes of my academic courses [17, 35, 41-43], and explored methods to combine elements

together that could create the high plausibility of physically being in the Flamman cinema in 1950.

- ***Development for VR*****:** In this phase, I addressed points stated in section 3.1) Objectives and 3.3) Expected Results*,* which required coding and modeling. The coding focused on engine specific features and the VR interaction framework, while modeling covered the environmental elements and texturing with its respective digital tools. Having the identified toolset, frameworks and methods that were considerably feasible, the aim was to develop a high fidelity experimental prototype that is fully reconstructing the Flamman building including its functioning cinema room along with providing the physics-based interaction forms. The idea was to model the interior in 3D using Blender [44]. For creating a well organized and performance efficient code implementation, the plan was to follow techniques that I learned in my academic courses. Additionally, enrich the 1950's atmosphere of cinema experience with audiovisual effects. Ultimately, I was able to partially answer the research question and verify that the concept of the combination of the selected tools and ideas were feasible.
- ***Qualitative Data Gathering:*** Using the completed experimental prototype, the plan was to gather qualitative data in forms of play testing sessions and interviews to evaluate the accuracy of the reconstructed Flamman experience. The raw data was documented in a spreadsheet.
- ***Results and Analysis:*** Begin with the spreadsheet containing the gathered qualitative data, the final step was to perform thematic analysis by finding common patterns to point out the relationship between factors and their possible causes. The results were planned to be summarized in a discussion, in comparison to the academic literature to draw the final conclusion and fully answer the research question stated in section 3.2) Research Questions.

5.3) Data Collection

5.3.1) Resources

Architectural blueprints (24 drawings) of the Flamman cinema theatre have been obtained from my academic supervisor, along with 119 photographs of the subjects that are taken from varying angles and distances. These photographs document, inter alia, the interior in historical time (4 photos), the exterior of the building (23 photos), the auditorium (53 photos) and the lobby (38) area in the present day, and a photograph of a movie ticket that has remained since 1945. The reconstruction process required me to rely on the photogrammetric correctness of the resources and 3D model subjects seen on these photographs in Blender modeling software. On the other hand, there was a necessity to gather textures from online sources that are identical to the real life counterparts. The created models were then exported as FBX files and assembled as a whole in Unity. In order to preserve the cultural heritage, other aspects regarding the NPC's appearance such as the outfits and hairstyles that used to be popular in 1950, Sweden, and the music of this time that was meant to be played in the lobby area required more investigation.

5.3.2) Development Experiments

The first set of the data gathering was regarding the findings made during the development process. This data set consists of various experiments regarding the probing of different implementation techniques along with the challenges that I faced. In parallel to this, I systematically populated this report with descriptive reasoning made on the results, along with the consolidation of external data sourced from online documentations. This collection is documented in section 7.Discussion, considerable as an empirical evidence in a strong relation to the resulting quality of the Flamman simulator, which were to be evaluated by the participants.

5.3.3) Alpha testing

During the reconstruction of the cinema with Unity game engine, each iteration went through testing with the VR headset to make sure that it was running and fulfils the expectations. One final alpha testing was also inducted whereas I went through most use case scenarios possible and probed the behaviour of the simulation for both the functional and non-functional requirements for eliminating flaws before reaching out to the participants.

5.3.4) Data Gathering

I considered the qualitative data gathering methodology with the conduction of observation via play test sessions and structured interviews as the most suitable technique considering the type of evidence to be collected important to evaluate the prototype. My interest was to formulate an opinion by assessing the participants' experience, emotions and sensual experience while being in the simulation. This experiment was done face-to-face with the participants (one by one) selected with purposive sampling (selective sampling) due to the pandemic. Therefore, the plan was to contact those people who could give meaningful feedback or work in the field of immersive technology, and be competent to critically evaluate virtual reality applications. The two data gathering procedures are listed below as DG2 and DG3.

DG2) Play Test: The tools of the experiment were the Oculus Quest 2 headset, the running Flamman cinema simulation, a sofa or armchair, and a bag of popcorn. The latter one is due to my assumption that people associate the scent of popcorn with cinemas. Therefore, other than the comfort of the sofa, I was hoping to cognitively manipulate the participants by their perception of smell, thereby creating the cinema atmosphere in real life. During the play test session, I observed the gameplay and asked the participant to think-aloud while exploring the cinema and performing tasks.

a) Preparation:

a.1) Setup the VR guardian: I set up the guardian (play area boundary) on Oculus near to the sofa / armchair.

a.2) Place popcorn: Prior to the start of play testing, I popped a bag of popcorn in a microwave oven and placed it close to the player area.

a.3) Sign agreement: The participant signed the consent form.

a.4) Equipped player: Participant standing in front of the sofa and mounts on the headset, then gets instructed on how to cast the screen.

a.5) Gameplay: The participant is told to think aloud while the gameplay is observed.

a.6) Take notes: I continuously take notes of the heard and seen observations.

b) Play Test Session:

b.1) Testing Hands Mode: Start Scene to Lobby Scene. The participant is told to select the Hands Mode at the Start Screen and only told to go and sit in for a movie. No furthermore instructions are given while being in the Lobby Scene. When entering the Auditorium Scene: the participant is told to walk around a bit. Then s/he is told to grab a chair pillow and put it down. By following that, I make sure s/he still stands in a safe position/orientation of the sofa and I tell him/her to sit down. When seated in real life, the participant is told to start the movie clip.

b.2) Testing Avatar Mode: The participant is instructed to select the Avatar Mode. Repeat the same process except for demanding to walk around in the auditorium.

DG2) Interview: The interview took place right after the play testing for which a set of questions were prepared in advance. The nature of these questions were predominantly oriented to assess the simulator. Supplementarily, a subset of foreground questions were asked primarily that contemplated the participant's tendency for cybersickness in general; comfort level and vision of the Oculus with or without eyeglasses; current hunger level; and whether s/he consumed caffeine containing beverage (while being hungry). These aspects have importance to the thematic analysis to investigate whether the experienced discomforts are in relation to these external factors, or the simulator itself was the causing factor of those. The next round of questions were dedicated to the evaluation of the simulator. The interviewees were asked to evaluate the identicality of the reconstructed Flamman by inspecting photographs of Flamman and comparing those to the virtual parts they saw. By following that, they were asked to evaluate the simulator's authenticity of realism in terms of understandability, usability, the mediated atmosphere, as well as the graphics. Ultimately, the interview was closed with open-ended questions that permitted each of the participants to express their valuation independently, which subsequently facilitated the discovery of hidden requirements. The interview questions can be found in Appendix A.

5.3.5) Documentation

Observation notes and answers gathered in DG1 and DG2 were documented in an electronic spreadsheet that was prepared for the next step, data analysis. This spreadsheet included the numbered questions that were arranged in rows in a single column, in a columned conjunction to my notes per participant. Each participant has been denoted by an unique ID in order to fulfil the statements made in the consent form, such as the guarantee of anonymity, including the exclusion of audio / video recordings.

5.4) Data Analysis Plan

The choice of data analysis method is dependent on the type of data that this thesis project requires for its completion. The ideal plan was to combine the qualitative data analysis together with the experimental design and development findings, the resulting quality of the product to be evaluated from the perspective of participants. Since the data collection forms a triangulation, therefore my choice was the conduction of thematic analysis in order to draw conclusions in this case. To begin with the analysis, I opened the spreadsheet that is the collection of the qualitative raw data, then followed the steps of thematic analysis as defined by [45][46], see table 5 below. The main task was to uncover themes in the data by finding similarities and relationships between different chunks of data that could be traced back to reveal the causing factors, e.g.: details in the answers given in relation to the answers given to the foreground questions. These causing factors /or the selected extracts were then furthermore analyzed in relation to the research questions. Ultimately, the results could be presented along with the comparison to the academic literature along with the discussion of the influential factors to draw the final conclusion.

Phase	***Description of Phase***
1. Familiarizing with data	*Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.*
2. Generating initial codes	*Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each other.*
3. Searching for themes	*Collating codes into potential themes, gathering all data relevant to each potential theme.*
4. Reviewing themes	*Checking if the themes work in relation to the code extracts (Level 1) and the entire data set (Level 2), generating a thematic "map" of the analysis.*
5. Defining and naming themes	*Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.*
6. Producing the report	*The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.*

Table 6. Steps of Thematic Analysis by Brun and Clarke [46]

Research Questions	Plan to Answer
RQ: *Which parts of the cinema going experience can be reconstructed, and which parts cannot or should not be reconstructed?*	Triangulation in the data collection (development experiments, DG1 play tests, DG2 interviews) and thematic analysis is required to come to the final disclosure.
Sub RQ: *What design elements are relevant to create a highly plausible simulation of a particular time and space?*	Conceptualizing elements by utilizing game design theories, immersive VR platform specific methods, and the induction of the cultural heritage preservation methods leads to the successful determination of elements to be reconstructed. This implementation can be experimented and evaluated by participants.
Sub RQ: *What is the resulting accuracy of plausibility regarding the overall simulation?*	The implementation solutions will highly affect the plausibility of the simulation. Furthermore analysis will be required to compare qualitative feedback, the results of thematic analysis opposed to the academic literature for the proof of concept needed to answer this question.
Sub RQ: *What factors cause limitations to the simulation in the sensation of the player's physical presence?*	Highly determinant by the technological affordances specific to the VR headset and the game engine. Revelable by the end of the development phase, that results in the identification of capabilities and limitations. Furthermore factors to be identified by the participants via the (DG 1) play tests and (DG2) interviews.

Table 7. Summary of Data Analysis Plan

5.5) Ethical Concerns

Ethical concerns arose during the data collection activity due to the fact that it was conducted in the form of play testing sessions under observation followed by an interview. According to the general research ethics and GDPR, I must have clearly communicated how the data of the participants will be processed; ensure their anonymity to build trust, and ask for their permission to present results in this research paper. However, the interview questions were mainly formulated to access the simulator rather than collecting sensitive data of the user. This agreement was made by signing the consent form prepared for the event. See Appendix B. On the other hand, the content of the film played in the virtual cinema could affect the participants' mindset individually [47] that could create bias in their feedback. Based on [48], the possible ethical consequences of the project are the same as those of the management of a real cinema. The probability of creating this risk is dependent on my selection choice of films and their type of content of which the participants are exposed to. In order to mitigate this issue, I made use of a film that has non-offensive content. In addition, I would like to emphasize that health concerns due to the ongoing pandemic of Covid-19 raised the most severe ethical concern. Being the interviewers, my responsibility was to obey the necessary precautions stated by the Public Health Agency of Sweden [49]. Therefore, I must have kept the physical distance, wear a face mask and medical gloves, and moreover, bring hand sanitizer and wipe the equipment in front of the participant - before and after each use. Yet, it was possible that some participants would refuse to meet face-to-face, and those who agreed to attend the physical meeting had the right to interrupt the ongoing play testing session any time.

6. EXECUTION AND PROCESS

The code implementation of the Flamman simulator can be found on Github.

6.1) Iterations

6.1.1) Iteration 1: 3D Modeling Elements of Flamman

Remaining photographic resources served as a basis for obtaining reliable information of physical objects within the cinema's environment preceding the first step, which was the modeling of the visible architectural and decorative elements. The images preserve the cinema in two separate eras. The first set of these photographs are still black and white as those were shot in its opening time of 1945. The colored sets were taken in 2020 in which the auditorium room drastically differs from its original installation, yet the chairs and the interior architecture remained the same, except for the wall paint and the flooring in general. This information was fetched from an additional source, from a small blog article [50] that gives textural description of the colors and the materials of those, such as the golden rough plaster of the arched ceiling and the red velvet seat covers. The architectural blueprint of the building documents several all the accessible halls and rooms, however none of the other resources has captured those visually. Driven by this reason is why I came to the decision to scale down the reconstruction and focus on the well known areas instead, however knowing that this will cause a limitation within the exploration of cinema as a whole. As a result, the accessible areas are the entrance along with the lobby including the stairway to the second floor corridor and the auditorium room.

On the other hand, the entrance area and the lobby windows must have the view to the street, however photographs of the surrounding buildings were missing elements as well. Unfortunately, the current Google street view images of the facing side of the street are all covered by a tram that was passing in parallel to the Google's street view photographer car during the capturement. Due to this inconvenience I must have travelled to the Flamman cinema myself and taken panorama photos at night time to avoid traffic and crowds. As I aimed for the year of 1950 and the high plausibility to this period, therefore the selected panorama picture was then retouched to vanish all the clues of modernity that were manifested in the forms of visible mobile phones, electric scooters, and modern cars for instance. Moreover, a significant reduction of the image's brightness and the raising of the contrast was necessary to hide details of the surrounding buildings, thereby avoiding the visibility of modern decorative elements both indoor and outdoor.

Digitally reconstructable elements were then identified to be those that could be seen on the images (tip-up chairs, arch decoration etc) but cannot be built from the primitive meshes that Unity provides, e.g.: plane, cube or sphere, and also those elements that are specifically unique to Flamman thereby cannot be obtained from external assets.

The task in Blender modeling software was then to build these unique parts such as the curved lobby with its bent staircase, ceiling arch and other decorative elements. Every object is static except for the interactive tip-up seats and doors. Therefore the latter ones consist of several pieces rather than one single mesh. The meshes are created with recalculated normals strictly to the outside only, thus the textures are rendered to the outside faces. Moreover, their polygon count was kept quite low for better performance by avoiding the use of the subdivision surface modifier and inserting edges manually. On the other hand, knowing that the chair object in the auditorium room sums up to 600, therefore the LOD groups (level of detail) technique has been utilized that is commonly used in AAA game engines as well. Thus a chair object consists of 4 versions of meshes, each with a unique identifier (chair_LOD0, chair_LOD1, chair_LOD2, chair_LOD3) and with a decimated number of polygons. The meshes were then exported as .FBX files to Unity, upon doing so, Unity recognizes the unique identifiers and creates the LOD Groups automatically while as well giving the privilege to set up the camera distancing per polygon versions. The advantage of working with LOD groups is that the camera renders the highest quality mesh of the object from close range, and switches to the next lower version if distancing from the object. Thus the object can become very primitive looking in case it is far away, yet it cannot be visually noticed by the player.

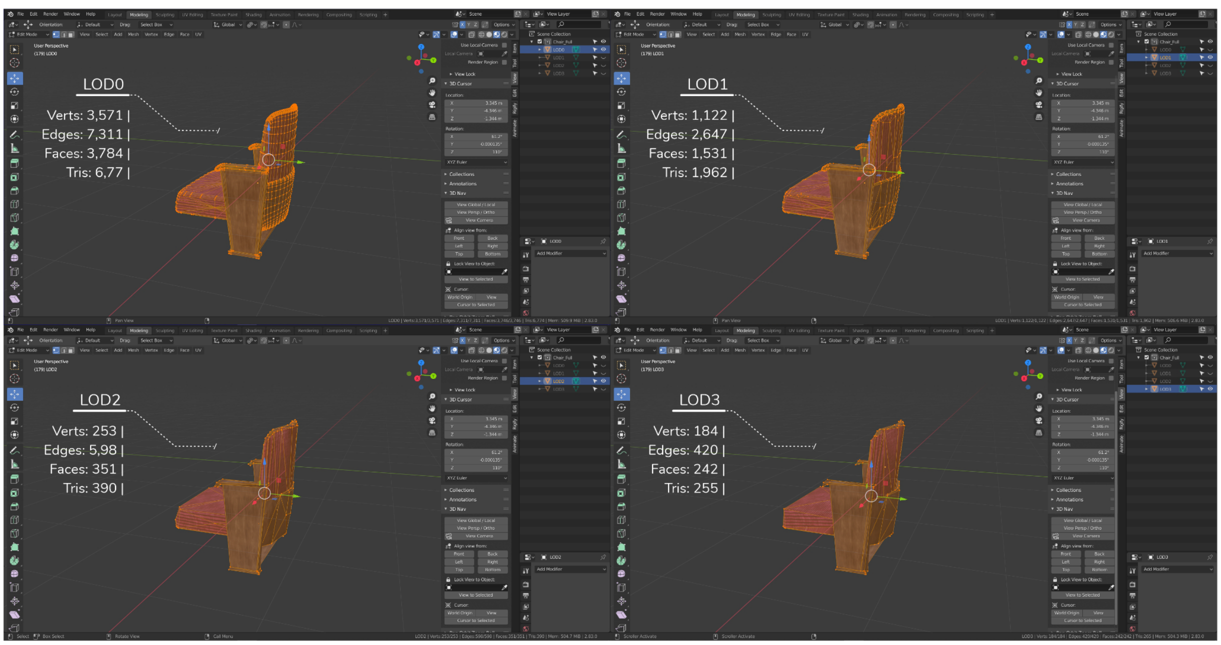

Figure 5. Levels of Chair Detail (LODs)
(Source: Personal collection, screenshot of Blender)

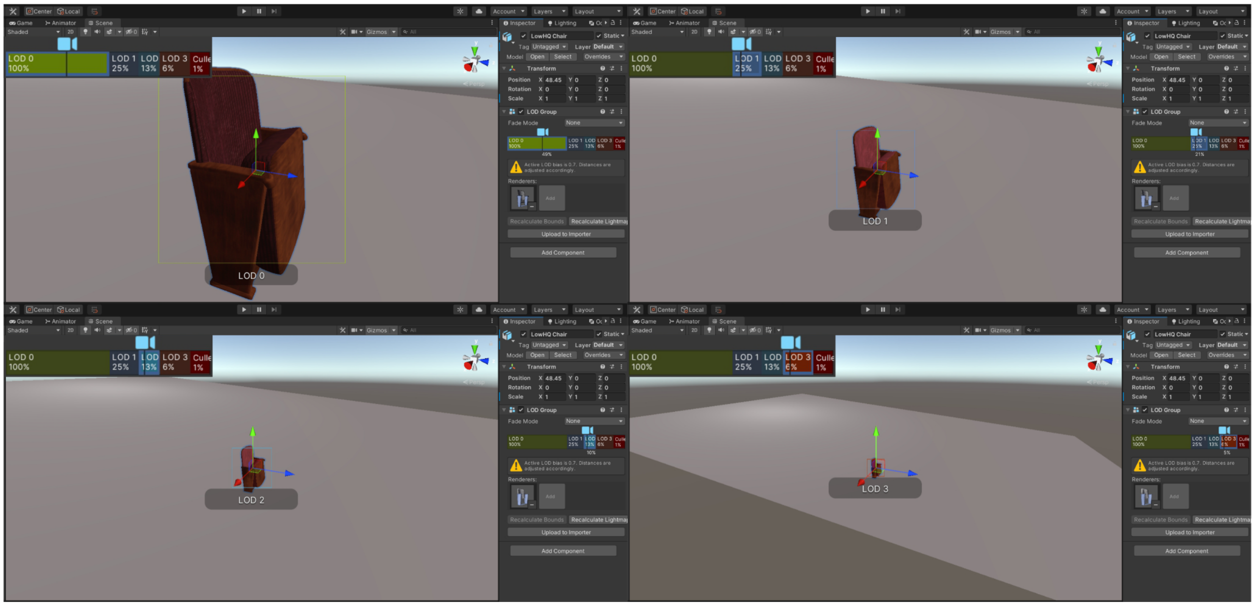

Figure 6. LOD Group: Switching of chair's LOD by Camera Distance
(Source: Personal collection, screenshot of Unity)

6.1.2) Iteration 2: Creation of Basic Cinema Simulator Prototype

The 3D models were then imported in Unity separately and assembled in the game engine. The reason for this is to have the ability to use occlusion culling, thereby the camera only has to render textures that are in the field of view, thereby raising the quality of performance. The setup of the unity project for Oculus Quest 2 development required installment of the Oculus Integration plugin and the settings configuration according to the online guide at developer.oculus.com [51]. The plugin supplies the user control scripts attached to the player prefab called `OVRPlayerController` which has the `OVRCameraRig` child object and the tracking space setup including the anchors for the eyes and the two arms. These scripts were then modified to support smooth and continuous rotation as originally it was defining a 45 degree snap turn via the thumbstick of the controller. Oculus Integration plugin as well supplies the fully animated custom hand prefabs that can be attached to the arms and use the `OVRGrabber` script for the ability to hold other objects in hand that are equipped with the pair, the `OVRGRabbable` script. However, this functionality had to be modified for the objects in the cinema that should not be grabbed out of their position such as the chairs in the auditorium with the tip-up mechanism or the doors. These interactive objects are based on physics with the use of rigidbodies and hinge joints rather than animations for the sake of providing an immersive interaction form, thus the player can grab the seat pillow and slowly put it up / down, or can just hold it in a position. Upon releasing an object the gravity and the springs defined for the hinge joints simulates the physical behaviour.

Priority aspect of the cinema simulator was the ability to watch video for which a canvas object is placed in the scene that renders an mp4 file locally from the file. Thus the auditorium scene was the first to be reconstructed, including the aspects of reading controller input for starting the movie and fade out the lights in the room. Additional player manager script has been written for controlling these events. The development of the lobby scene was subsequent to the auditorium which as well has scripts written for the events of purchasing a ticket and unlocking the doors using trigger zones and user input along with textural goal indicator outputs for the first prototype. The lobby room uses multiple light sources in baked mode, while the auditorium is equipped with real-time lights. After some experiments with the provision of high quality textures and multiple real-time lightings, some deduction took place for raising the quality of the overall performance instead. These decisions were manifested in the removal of some shadows, reflections, and the reduction of the compressed texture qualities.

The initial prototype supported the following flow of events. The player spawns at the entrance door downstairs, walks to the ticket booth whereas a text pops up and prompts the user to purchase a movie ticket. The player presses the button on the controller to complete the fictive purchasement. As next, the player can walk up to the stairs but cannot open the doors to walk into the auditorium room uless "showing" the ticket to the cinema usher who is represented via a pop up text in front of the door. The player gains access once s/he has a ticket that has been shown. The player opens the door and walks into a scene trigger zone from where s/he will be transited to the auditorium scene. In the auditorium room, the player can start the move with the controller button whenever s/he wishes to do so, accordingly the lights fade out and back in when the movie is stopped.

6.1.3) Iteration 3: Creation of Non-Player Characters

The reason for this iteration is due to the fact that the interaction embedded in the first prototype was considerably inappropriate. Visual goal indicators in simulation games somewhat violate the plausibility of the game world once aiming for a truly realistic representation of the real physical world. It is unrealistic to visualize a pop-up text stating to press a button to perform an action, however, this is something that usually gets forgiven or even unnoticed to those who are really sensitive about the extreme plausibility. The reason for that could be due to the expectation towards consistency, as how digital products commonly have goal indicators and how those products usually include the perceivable feedback of state.

Another issue with the first prototype is that pop-up texts are inadequate in a cinema simulator which creates the manifestation of loneliness, social emptiness. A cinema is usually crowded with people, however multiplayer mode is not considered for this simulator yet. Therefore, I believed that the interaction with at least the cinema workers must be included. At this point I returned to Blender and modeled two non-player characters from scratch wearing old fashioned cinema usher uniforms; a female to stand in the ticket booth, and a male for the usher role at the door. Unfortunately, the photographic resources did not capture the worn uniforms within Flamman. Hence my assumption was that perhaps red and gold colors conclusively match the style of the auditorium room as well bearing in mind that miniature details such as the appropriate hairstyle and the makeup trend of the 50's must be considered. Therefore, the female character has texture paint on the face for makeup that consists of black eye liner, moderate amount of blush and lipstick. Depending on the decade, the appearance is very important for representing the cultural heritage and staying true to the facts. As my intention was to exchange the goal indicator pop-up texts to the interaction with these cinema worker NPCs, therefore these models had to be equipped with voice and body gestures. Several game asset provider websites offer downloadable animations. However, those are typically made for action game characters, thus those animations are focusing on movement and combat moves in general that cannot be used for this simulator. That is true to the simple idle animations which are also unsuitable for the cinema ushers over and above since politeness in the 50's was a trend to the extent that if a staff member had to stand by to greet the guests was usually an act in accordance with the gentlemen's body language etiquette. Nowadays this is neglected in the public places excluding the elite groups, as for instance a receptionist may keep looking at the monitor while remaining seated. I assume that gentleman's body posture was practiced independently of classification back then, so that the guests were welcomed in the Flamman cinema the same way as if they would visit a fine dining restaurant today. To recreate this aesthetic, I had no choice but to make the animations from scratch as well. To do so, I have rigged up the two humanoid models and for each I have created non-linear animations (NLA) of the different states according to their roles within the cinema:

- ***Animations of Cinema Usherette:*** *[{idle}, {greet_prompt_buyin_ticket} {waiting_for_decision}, {complete_purhcasement}]*
- **Animations of Cinema Usher:** *[{idle}, {greet_prompt_showing_ticket}, {waiting_for_decision}, {refuse_access}, {give_access}]*

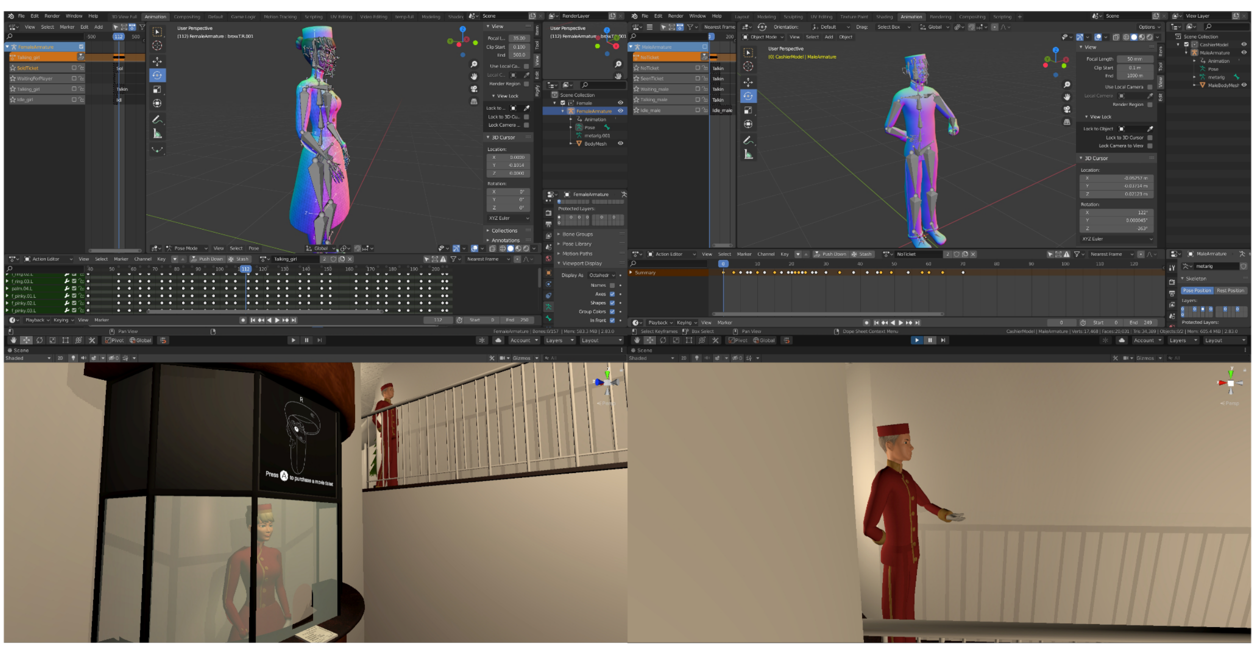

Figure 7. Modeling and Animating the Cinema Workers
(Source: Personal collection, screenshot of Blender and Unity)

The NPCs are given voice over scripts that are synced with the keyframes per animation. Their monologues are basically audio files created by the "generate speech from text" feature available on the website voicechanger.io [52]. Blender's NLA enables the creator to assign multiple animations for a single object and the privilege to include these animation datas when converting this object into FBX format. Thus, when importing the object as a prefab into Unity will include all of its animations conveniently. Unfortunately, audio data cannot be stored in FBX, therefore those must have been added manually to the Unity project. The final task was then to imitate at least a minimal level of NPC AI for which the creation of animation controller components and the design of the state machines was next. NPC were placed in the 3D environment to their position (ticket boot, door) with scripts to invoke animations and define which audio clip to be played per action event. Now that the simulator got enriched with NPC bots and audio goal indicators, furthermore sound effects for the sake of imitation of 1950's cinema aesthetics have been implemented such as the distant music played in the lobby, or the door's creaking sound effect. The sounds are spatialized meaning that the audio sources given by their position in 3D space spreads around 360 degrees and fades out by distancing. Moreover, the sounds are in stereo and can be heard louder for an ear than the other one depending on where the player turns his / her head.

6.1.4) Iteration 4: IK Avatar Mode

As mentioned in 5.1.2, animated custom hands are included in the Oculus Integration plugin that essentially features the real-time hand and head position and orientation tracking by receiving data from the inbuilt 6DOF sensors of the headset. Thus the player can walk around, turn his/her head and grab the objects in first-person mode which is yet limited to see the hands only. `OVRPlayerController` prefab is only an empty gameobject with a capsule collider, it does not include a body mesh nor the armature, only the head and the anchor points of the arms are set. Visualizing hands or at least the controllers is a common practice of VR applications that is indispensable in cases when the hand orientation must be known to the player, especially if the game dynamics relies on that data. As my proposition was a realistic simulator, I created a mode where the player can embody an avatar given by the ability to see the limbs.

Based on the anatomy of the human eyes, our visual capabilities regarding the horizontal field of view is approximately 180 ° - 200 °, and 150 ° of the vertical range of the visual field. `OVRCameraRig` is capable of simulating this attribute by the definition of different visual ranges that can be set for the displays of the Oculus headset. `LeftEyeAnchor` and `RightEyeAnchor` with the clipping planes of near and far distance set for the same wide and distance value, and a narrower but longer range for the `CenterEyeAnchor`. These ranges should be uniformly set compared to each other to keep the same aspect ratio, but not necessarily must define a reality-exact range. The importance of the ratio is to avoid rendering issues during occlusion culling for instance, when an object ahead is in distance range for one eye only. Since `OVRCameraRig` replaces the traditional game camera and the fact that the headset is mounted on the head, therefore defining the field of view for these three anchor points must be carefully done. Thus the view should not be too wide as other than creating discomfort to the eye, it could cause performance issues as more game objects can be rendered at the same time. Contrary to this, the field of view should not be too narrow either as turning the head in such a case could lead to cybersickness. By following this setup, I addressed the need for the avatar for which I downloaded a rigged character mesh from maximo.com [53] including animations for the defining the basic movements such as [{idle}, {walk forward}, {walk backward}, {turn left}, {turn right}]. The character is faceless and unclad, being objectively alike a mannequin doll. My selection choice towards this mesh was driven by the reason that both the self representation and the cultural representation via a protagonist is relatively unimportant in a single player first-person mode game as the full appearance would remain hidden unless there are reflection probes in the environment such as mirrors. Embodying a full avatar yet required the provision of *thin character as mask* [21] since anatomy and the bilateral symmetry constitutes high relevance in the mediation of realism, and from this aspect, inverse kinematics (IK) as well.

The setup of inverse kinematics required the preparation of end effector bones defined for the bones of the character's rig. As its name indicates, inverse kinematics is the opposite of forward kinematics when it comes to the computation of the end effectors. Instead of influencing bones that are forward down the chain, inverse kinematics allows the transformation of a bone near the end of the chain to influence bones that are further up in the chain of bones and with that the child bone has influence over its parent bone. For instance, when moving the hand bone, the upper arm and forearm bones will determine where they have to be to accomplish that movement. Moreover, the definition of effector or target bones should be moved independently in order to avoid cyclic dependency and enable the elbow or the knee to bend naturally. To do this in Unity, I installed the Animation Rigging package and utilized the `RigBuilder` and `BoneRenderer` scripts to assign and visualize all the bones of the character. By following that, I defined the IK constraints in the next step. First I created an additional game object under the player called VRConstraints with the following child objects:

- ❏ `Right Arm IK`
  - ❏ `target`
  - ❏ `hint`
- ❏ `Left Arm IK`
  - ❏ `target`
  - ❏ `hint`
- ❏ `Head Constraint`

The position of `target` and `hint` child objects in both are matched with a corresponding bone.

- `Target` (gam object): {`Transform`} = `Align Transform` with the hand's wrist joint
- `Hint` (game object): {`Transform`} = `Align Transform` with the arm's forearm joint.
- `Head Constraint` (game object): {`Transform`} = `Align Transform` with the head bone of the rig.

Figure 8. Effector Bones of Rig
(Source: Personal illustration)

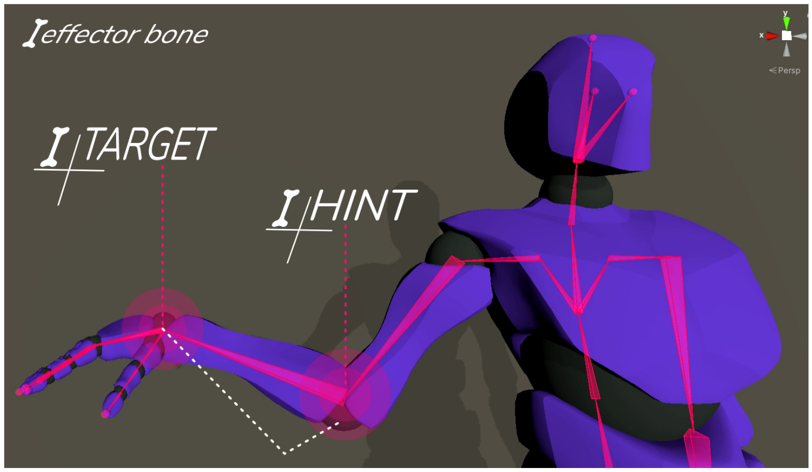

Figure 9. IK: Target and Hint Positions
(Source: Personal illustration made with Corel Draw X9)

`Left Arm IK` and `Right Arm IK` uses the Animation Rigging plugin's `Two-BoneIKConstraints` script where I assigned the hierarchy of bones. First of all, the bone chain dependency, inter alia, the root = upper arm, mid = forearm, tip = hand; then `target` and `hint` child objects for the source objects properties. `Head Constraint` uses the `MultiParentContraints` script in which the head bone is referenced as a constrained object. For the legs the walking animations are checked with the IK pass parameter in the animator controller along with avatar masks to influence the legs only instead of the entire body which is essential to avoid overwriting the position of arms and the head since the orientation of those are to be controlled by the player via the VR controllers. The inverse kinematics for the legs are defined by a script that accesses the animation controller and uses raycast to perform ground checks in a library function called `OnAnimationIK.`For instance, if the foot touches the ground, it gets a weight of 1 assigned which is the amount of influence the IK will impact the animation. The weight is defined between the range of 0 to 1 where 0 means no collision with the ground. IK pass together with the avatar mask automatically bends joints within the bone chain of the leg upon ground check and distance from ground. By the end of this process I was able to define inverse kinematics, thus the limbs were properly moving and bending according to the positioning of the effector bones and ray tracing. The ultimate task was to enable the control of the full body avatar via the Oculus Quest 2 headset and controllers which meant the mapping of this avatar model with the underlying OVR foundation, specifically with the `OVRPlayerController` prefab.

The fusion of the body avatar with the existing `OVRPlayerController` required the positioning of the two onto the same coordinates by the categorization of both under a new empty game object that was called "Player" at this point. Then the reference of the effector bones within the appropriate game object of the `TrackingSpace` by creating three empty game objects: `HEAD`, `LEFT HAND` and `RIGHT HAND`. Their task is to set position for the effectors, to the `target`(s) of the avatar's arms when the player is moving the controllers, subsequently the IK will be performed on the bones. To do so, the avatar model has a script in which I reference these game objects located in the TrackingSpace to get their position updates and assign those values to the effectors. At this point, the game objects moved by the headset became the ultimate drivers of the effectors of the avatar rig, such as: `HEAD <- Head Constraints`, `LEFT HAND <- Right Arm IK (target)`, `LEFT HAND <- Left Arm IK (target)`. See image of fully mapped OVR avatar below.

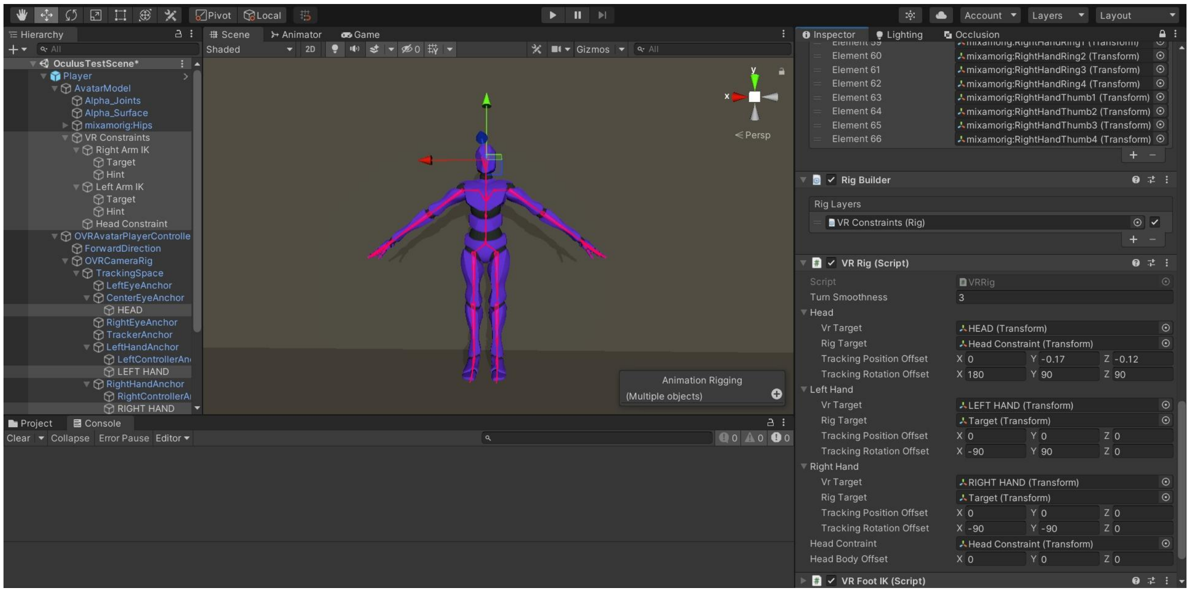

Figure 10. Mapped OVR Avatar
(Source: Personal illustration, screenshot taken from Unity)

6.2) Development Experiments

6.2.1) Design for Motion Sickness

Discomfort and blurriness due to the wearing of the VR headset cannot be 100% avoided, however it seems that the replacement of the strap with Elit Strap has effectively stabilized the headset. The pressure on the face is still a remaining issue that can shorten the play time duration before cybersickness symptoms start to occur. Aside from the inconveniences of wearing the headset, there are plenty of obligations that a VR game developer should keep in mind. First of all, design choices to be made in order to avoid motion sickness [54] utilized together with the techniques mentioned in [4-6].

An important aspect is to minimize motion in the scene, however, the Flamman simulator is not an obstacle course with moving objects, yet the player can turn in the 3D environment which results in the sudden motion of the entire field of view. According to the study of joystick control in VR [55], the proper setup of discrete rotations causes significantly less motion sickness than the field-of-view reduction. As mentioned before, the scripting of basic character controls were included in the `OVRPlayerController` prefab with its default settings [56] that originally defined the snap turn mapped to the thumb stick by the following values: `rotation amount = 1.5`, `rotation ratchet = 45` degrees, `acceleration = 0.1`, `speed rotation increment = 0.05`.

On the other hand, the settings regarding the field of view seemed to be suitable, although I adjusted the boundary value of the far plane to the size of the scene, purposefully for more efficient occlusion culling. The advantage of using the Oculus Integration plugin is that the player has control over the walking speed by the precision measurement of the thumbstick embedded in the source code of the `OVRPlayerController` script. Thus the speed is operatively dependent on how radical the thumbstick gets moved from its default center position. The disadvantage of using the default snap turn was due to its setting which defines a rapid 45 degree turn made every time the rotation thumbstick was pushed once. First of all, rapid motion perceived in the headset is uncomfortable for the eyes. Secondarily, snap turns by any value feel unrealistic in first person mode.

Thirdly, the characteristics of the building could cause limited visibility in this case, which was experienced by the issue of keeping the camera's orientation facing forward while walking on the curved staircase was thereby impossible. Driven by these reasons, it was necessary to switch from snap turn to continuous smooth turn with the modification of the `rotation ratchet` value from 45 to 360 degrees, and by setting the `snap turn` boolean to false. As a result, the player could be in full charge of the rotation amount and its speed, all of which can be performed preferably slower or faster to an amount based on will.

6.2.2) Attempt for Realistic Lights

6.2.2.A) HDRP

The original plan was to explore the cinema's `Lobby Scene` during the daytime which would have included soft particle sun rays coming through the windows, with the highest quality of reflections and shadows. My aim was to use Unity's High Definition Render Pipeline (HDRP) [57] since it includes a large list of graphical tools, thereby I would have been able to create higher fidelity graphical effects for the lamps in general that are placed on the ceiling of the corridor and in the Auditorium Scene. Ultra realistic lighting effects just as the volumetric light beam type of light is featured by Unity's HDPR package, or can be reached via the popular "Volumetric Light Beam" [58] VFX shader plugin that could be purchased from the Unity Asset store. Unfortunately, HDRP could not be used as it requires the Vulcan graphics rendering API. According to the rendering preferences settings [59] for Oculus Quests, the selection of OpenGL ES [60] 3.0 graphics API is highly recommended as Vulcan is yet under experiment. Due to this requirement of the Oculus Integration plugin, I must have relinquished the idea of using HDRP and downgrade the project to use Unity's Built-in Render Pipeline instead.

6.2.2.B) Post-processing

Next attempt was the utilization of Unity's post-processing [61] package to reach the target attributes mentioned above. The experiment regarding the enrichment of the visuals was extensive to the application of the following effects, inter alia, *`Ambient Occlusion`* (better corner shadowing, e.g.: joints of walls and floor), *`Glow`* (effect to the lamps), *`Motion blur`* (with a low value to slightly blur the camera in the direction of motion), *`Dept of Field`* (to blur distant objects in background), *`Vignette`* (an almost invisible darkened corners on the camera to imitate vintageness of the simulation), and *Color Adjustments* (better brightness and contrast). Except for two excluded effects in this project, the post-processing package is compatible with the Built-in Render Pipeline without the prerequisite of additional platform-specific requirements to be set under the player settings. The only difference between the usual way of setting up the post-processing effect is that it is added to the CenterEyeAnchor of the OVRCameraRig game object which represents the main camera in this case. The combination of these effects gave more life to the scenes through the camera that could be seen during the runtime in Unity, however, all of the post-processing effects were lost the moment when the project was built to the target platform. Thus none of the effects were visualized in Oculus. Unfortunately, the root of the problem remained unknown, therefore the use of the post-processing effects had to be deprecated as well.

6.2.2.C) Implemented Lighting Solutions

Since neither of the HDRP nor the Post-processing was an option, the solution was to falsify the illusion of volumetric lights with the use of the emission property of the materials set for the light game objects (mesh) with additional point lights beneath them to simulate the "halo" effect, along with the use of particle system effects for creating light rays. Note that the "halo" effect is a selectable property of the type <Light> in Unity, however such can only cast a spherical light beam of the same color, range and intensity of the particular light. Regardless if it is enabled for a spotlight, the halo effect cannot cast cone shaped light thereby it would not be realistic. To support this effect for the spotlights as well, a particle system was created in the shape of a cone with settings similar to the example in [62]. Without post-processing effects, the privilege regarding the camera effects are nonexistent to the developer. The least I could do for the multi ranging colors was to set the lights in different tones ranging from warm to cool tones and make them differ in brightness compared to each other - keeping in mind that amplified light intensity could cause severe discomfort to the eyes -this gave at least a minimal lifeness to the scenes. Regarding the Auditorium Scene, the color (r,g,b) and alpha values of the lights are scripted to perform the following transition: fade out when the movie starts making the room dark with a deemed blue light; and fade back when the movie is finished. The transition time of the fading was set to slow, thereby smoothed to avoid rapid changes in brightness that could also cause discomfort to the eyes, which would subsequently lead to cybersickness.

7. RESULTS

7.1) Development Experiments Results

7.1.1) Frame Rate Issues

The simulator's `Auditorium Scene` meant significant threat to the FPS given its characteristics of being heavily packed of chairs (600), myriad number of switchable light sources and an HD video player representing the cinema canvas. I begin the reconstruction with highly realistic visualization of fabrics by using 4K and 8K images for object materials, including the chairs. The result was stunning when looking at objects from close range, unfortunately the frame lag was severely detectable during the runtime of the game which worsened when the particular scene was evolved with additional elements. Each object has a texture and mesh renderer consisting of hundreds of polygons alone. All above that, more real-time light sources were placed for the proper room illumination and shading that together would produce the lifelike representation of dimensions and depths. When I inspected the rendering statistics in Unity during the runtime, my finding was that the triangle count derived from the sum of the triangles - gathered from all of the meshes placed into the scene - had been multiplied by the number of scene lights which summed up to millions of triangles and thousands of vertices. These values significantly differ from the original triangle count of the object mesh when it was created in Blender, in which I paid great attention to keep the maximum polygon count low during the modeling therewithal. The light sources multiplying the triangle count leads to more draw calls for the total number of meshes after batching was applied. Objects are rendered multiple times if illuminated by pixel lights, therefore each rendering results in a separate draw call. Even worse if working with real-time lights. Such has continuous calculations to draw light on surfaces therefore it is known to be computationally expensive as it gets updated every frame. The amount of real-time lights on the scene could lead to an extreme degradation of performance. Moreover, low FPS has a multiplicative effect on the ongoing lag of the VR hand-tracking if the interactable objects are small [63] which can be manifested in the reduction in responsiveness of the controls. This scenario could be experienced in this particular simulator as well, observed during the interaction with small objects such as the relatively small movie ticket, and the chair pillow's invisible handle. Lag would not be as crucial to the Flamman simulator as for an online multiplayer game, notwithstanding to this, the player must be able to explore and interact with the digital environment without lag that is crucial to avoid cybersickness [4], moreover to support the plausible Loyalty to World [21] through an almost lifeline experience [3].

7.1.2) Performance Optimization

In order to ensure the smooth run of the simulation, the task was to reduce the draw calls with the decimation of polygons per meshes, subsequently the number objects with mesh renderers, and the number of light sources, and most importantly, the number of objects to be rendered to the camera's field of view during run time. Combined use of performance optimization techniques listed as ***PO_n*** were fulfilled, with the drastic downgrade of the graphics which contributed to the digitalistic look of the simulator as told by participants.

7.1.2.A) PO_1: Removal of Particle Systems

First step was the shift from daytime mode to the simulation of evening, thereby resolving the need of the falsified volumetric light beams casted via particles through the windows. As well, this particle system effect had to be removed from all the additional lights placed in the scenes for the reason that particles are emitted in real-time which had a large performance cost. However a particle system alone does not require the emission of loads of particles per second to create the desired effect, yet they were summed up to a significant amount together with the rest of particles emitted by other particle systems on the scene. The FPS counter could be increased after disabling the aforementioned effects, thereby those became deprecated. This decision negatively affected the sensation of realism to the extent that was not so obvious to the participants who tested the simulator.

7.1.2.B) PO_2: Switch From Realtime to Baked Lights

The second optimization technique was to terminate the use of the realtime lights in the most problematic scene, the `Auditorium Scene`. To begin with the shift, I switched to baked mode per `<Light>` then generated a lightmap. This process is known as baking which is the calculation of the lighting for objects in the scene saved as lighting data. Thereby loading this lightmap at runtime could significantly reduce the shading and rendering cost as the lighting calculations were done upfront which subsequently reduced the draw calls. The downside of baked lights leads to visual dullness, which in this case was also noticed by the participants during the play test session. Usually games have mixed lights, this way most of the lights are baked to the static geometries while having at least a few light sources rendered in real time for stunning results. Unfortunately, the presence of even just one real time light could not be afforded in the `Auditorium Scene` due to the number of seats for which the calculations of fractions and reflection probes were performance heavy. On the other hand, there was a problem to be solved regarding the switching on and off the lights based on the status of the video player. The aforementioned technique of fading transitions requires the light mode to be realtime in order to be changeable during runtime. Disadvantageously, disabling /enabling of a baked lightmap is not featured by Unity, neither the switching between lightmap versions during runtime is an option as each scene can store one lightmap data at a time. The finding of a solution to this problem became imperative since the feature of switching lights cannot be deprecated, thus the lights must turn off when the movie is playing otherwise causing a defacement to the authentic simulation important from the aspects of [1,3,9]. Fortunately, a solution was discovered in the form of falsification of the sensation of dark room with the technique of projection of a dark, single colored image via the `Projector` effect that is a part of Unity's standard assets [64]. This way, the room could remain illuminated by the baked lightmap - yet with the possibility to become eclipsed by this overlay of darkness when the movie starts.

7.1.2.C) PO_3: LOD Groups and Downgraded Quality of Textures

This technique was the most effective optimization that raised the FPS counter back to the adequate level of playability which had a drastically noxious effect on the quality of graphics. First of all, the 600 seats of the `Auditorium Scene` were rendering 4K textures all with specular highlights and reflection probes enabled for ultra graphics, and around a thousand polygons per chair constituted the mesh data of each. However now there were no realtime lights which multiplied this amount, yet the polygons and the rendered texture quality was menace to the frame rate during run time. The decrasement of polygons per chair meant a rework to be done in Blender, in which I created three versions of meshes, each with less polygons then re-imported them in Unity as `LOD Groups`. This way the distant objects are visible to the camera, however their details are dramatically reduced without the player can notice that. On the other hand, the textures had to be downgraded to low quality, thus the removal of specular highlights and reflection probes for the materials were disabled. As well as the removal of the normal map and the heightmap properties took place per material, allowing only the albedo image texture which is a small sized, compressed image. The `LOD Groups` are then setup to render different quality versions of the materials; `LOD_0` which is the most detailed mesh object renders the above mentioned quality of the texture material that is now the best quality; while `LOD_1` and `LOD_2` gets a less clear texture material, eventually `LOD_3` receives only colors instead of textures. This optimized performance is guaranteed with the provision of intentionally excluding the seats from receiving the dark image by the `Projector` while the movie is playing, which means that the chairs remain bright when the room is darkened. To resolve the obvious differences in brightness, lines of code were added to the manager script responsible for events in the `Auditorium Scene` to access the material components of the chairs objects and simply set their color black when the movie is playing, and white when the movie is finished. These colors are applied as an overlay on the material's albedo texture itself, another cost efficient solution since it works with the original textures that are already rendered.

7.1.2.D) PO_4: Occlusion Culling

Effective solution which increased the rendering performance by the definition of dynamic exclusion of geometries that are outside the camera's view frustum, and those that are visually obstructed by other objects. This way the Lobby Scene's corridor upstairs gets entirely diabled from the rendering till the player walks up on the stairs and looks into that direction. Similarly to this, only those cinema chairs of the Auditorium Scene are rendered that are currently in the camera's field of view. Occlusion culling has only benefits regardless of the camera's speed in terms of changing direction and rotation as it remains completely unnoticeable for the player.

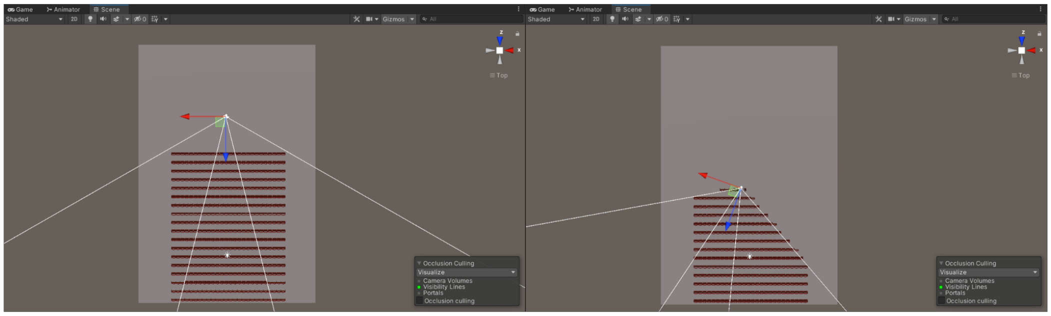

Figure 11. Occlusion Culling

(Source: Personal Collection, Screenshot of Unity)

7.2) Influential Factors on Quality

Requirements of the target platform and the capabilities of the chosen game engine determined the technological affordances to this project mostly. Next to this, multiple influential factors impacted the overall provision of elements that are compositional to the quality of the Flamman experience to the detriment of those. The following points answer the research question by identifying the influential factors on quality in the reconstruction of the Flamman experience.

7.2.1) Factor 1: Information Availability

The availability of information determines what can be reconstructed and what cannot be. Subsequently, the quality and accuracy of the resonctructble element relies on the information quality. The more famous or important the environment is historically or culturally, the more documentation can be found of it. These could be guest or visitor lists, textural descriptions, blueprints, photographs, videos, and interviews with people who were there. The task is to gather all the information that can be found and work from a variety of sources in order to gain a deep knowledge of knowing what to restore. Mismatching reconstruction of the respected space and time decreases the quality of the simulation.

The Flamman cinema could be reconstructed from photographs: black and white photos of the entrance, the lobby and the auditorium; colored pictures taken in modern time with a changed interior.

7.2.2) Factor 2: Architectural Complexity

The architectural characteristics of the reconstructable environment is the second influential factor to the quality. A large and complex building that is excessively furnished and decorated with art burdens the modeling process. Such characteristics require higher effort in the reconstruction which is time consuming and difficult. The overall size and detail of the digitally reconstructed environment is a potential threat to the GPU and CPU performance of the target device for which decisions have to be made that risks the quality regarding the accuracy and richness of the simulator.

The Flamman cinema has simple architectural complexity, however it has a large number of furnishings: 600 chairs in the auditorium room.

7.2.3) Factor 3: Technological Affordances

The third influential factor identified to be the technologies used to develop and run the simulator. Technological affordances are dependent on the capabilities of the selected game engine and the target device which has its own non-functional requirements to be followed. For instance, these could be the configurations of the game engine to fulfil requirements preferred by the target device such as quality settings regarding the rendering, shadows and the settings of the graphics. This means that the maximum quality is always predefined and remains limited by the technological affordances of the chosen softwares and hardwares, therefore, the graphics cannot exceed that top quality. Photorealistic graphical implementation is possible, however if paired with *7.2.2) Factor 2: Architectural Complexity*, then the rendering of many objects with photorealistic graphics could be undurable for both the game engine and the target device. Inasmuch as it becomes necessary to react with the intentional simplification of the virtual environment and reductions in the graphics.

In this project Unity game engine was used for the development and the target device was Oculus Quest 2. Neither of them could endure 600 chairs, dynamic lights and HD textures, the simulator was running on low FPS.

7.2.4) Factor 4: Game Performance Optimization

As *7.2.3) Factor 3: Technological Affordances* determines the quality of graphics and game performance, the possibilities to remedy problems by optimization techniques are dependent on the chosen game engine alone. It is possible to release the reliance on a commercial game engine, thereby one can have more control over the game performance by using a self made game engine. However, this independence requires the developer(s) to be highly competent in game engine development and have deep knowledge in the field of computer graphics. If the performance optimizations were done efficiently, then the sacrifices that were made can be reverted to some extent, thereby supporting the aspects of authentic reconstruction together with the graphical realism. Nevertheless, the maximum quality that is defined by the capabilities of the target device remains the determining factor on quality.

In this project, optimization techniques were utilized that were possible by the chosen game engine, Unity: 7.1.2.A) PO_1: Removal of Particle Systems, 7.1.2.B) PO_2: Switch From Realtime to Baked Lights, 7.1.2.C) PO_3: LOD Groups and Downgraded Quality of Textures, 7.1.2.D) PO_4: Occlusion Culling.

7.2.5) Factor 5: Definition of Player in VE

If the previous factors would have given severity points, then this factor should be rated the most severe influential factor amongst all. The user's eyesight and movement in the VE can be influenced by the developer’s choices when implementing the game cameras and controls. These will be direct influences to the visual stimuli and the user’s vestibular system. Game camera anchors should be placed on a certain distance from the floor that represents an average human height while their FOVs should be set to recreate the ranges of the human vision. VR controllers should be mapped with the virtual hands, thus when the user makes a gesture with the controller, the appropriate virtual hand follows that.

In case of an untethered VR device, the controller driven avatar's movement should be defined with values that produce a realistic walking speed and slow turning speed with continuous movement. The thumbstick controllable parts shall only map the avatar's body excluding the head in order to let the user decide the gaze or focus point in a natural manner. Thus the head which has the cameras for eyes should be controllable by the user's head orientation only. There are VR games in which the embodied avatar is translated according to the head orientation. In this simulator, the body of the avatar does not turn instantly till a 180 degree horizontal head movement is reached. Meaning that it is possible to look at different angles within this range while walking straight or even when turning with the thumbsticks. Moreover, if animations are used on the avatar, then those must be excluded to overwrite the movement of the head.

Immersiveness can be raised in VR by letting the user embody a full body avatar that has the definition of inverse kinematics by using invisible effector bones in a hierarchic order to follow the orientation of the hand. Thus when the player gestures or moves, s/he will be able to see the avatar's upper arm which follows the movement by bending the elbow and the knees. If animations are used for walking, then those should be masked on the legs only, however the step height should be following the virtual terrain by using continuous raycasting to track the floor below the virtual feet. Therefore, walking on the staircase can be very realistic. Any forced movement such as snapping the camera or animating the neck must be avoided as it would be a confusing visual stimuli which phenomenon is known to be the causal factor of motion sickness.

In this project, the cameras were defined with FOV reduction (wide clipping planes for the left and right eye camera, and a narrower center eye camera) and controls with continuous turning to avoid motion sickness. Moreover the player can choose between modes: Hands Mode or Avatar Mode (with inverse kinematics). Both of them define the same vision and motion within the Flamman's environment.

7.3) Resulting Flamman Simulator

The following section references some of the relevant game design patterns of Björk et.al [25] denoted in italics here. The detailed description of those can be seen in [65].

7.3.1) Game Mechanics

Flamman cinema simulator is a *single-player* simulation game built for exploring the once existent building relevant from the aspect of cultural heritage. The prototype provides fully explorable game areas that are limited to cinema's lobby and the auditorium room, therefore also featuring *inaccessible areas* such as the street blocked by *invisible walls* located on the outside of the entrance door, moreover the AI of the *conditional passageways* between the `Lobby Scene` and the `Auditorium Scene`. The simulator is partitioned into subsets of scenes with loading cycles which can be experienced as a second of freeze followed by a blackout when making a transition between those. The first scene is the `Start Scene` where the options to select the `Hands Mode` or `Avatar Mode` is given, then the simulation begins by *spawning* the player in the `Lobby Scene`.

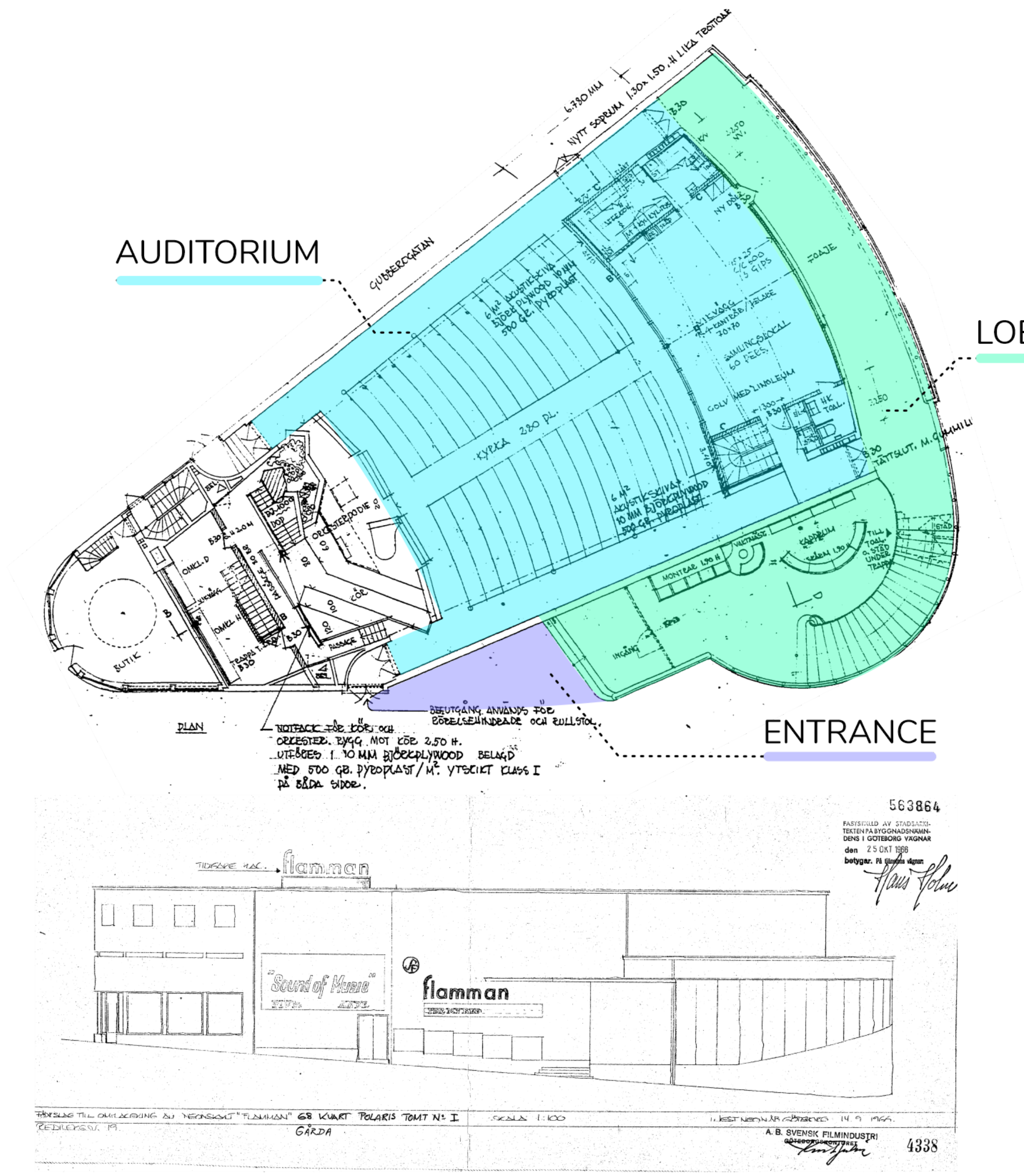

Figure 12. Reconstructed Accessible Areas

Entrance area Lobby Auditorium

(Source: Personal illustration made with Corel Draw X9 on blueprints obtained from my academic supervisor)

Figure 13. Lobby: Screenshot of Game Compared to Photo Evidence
(Source: Obtained photographs from my academic supervisor with screenshots taken from Unity)

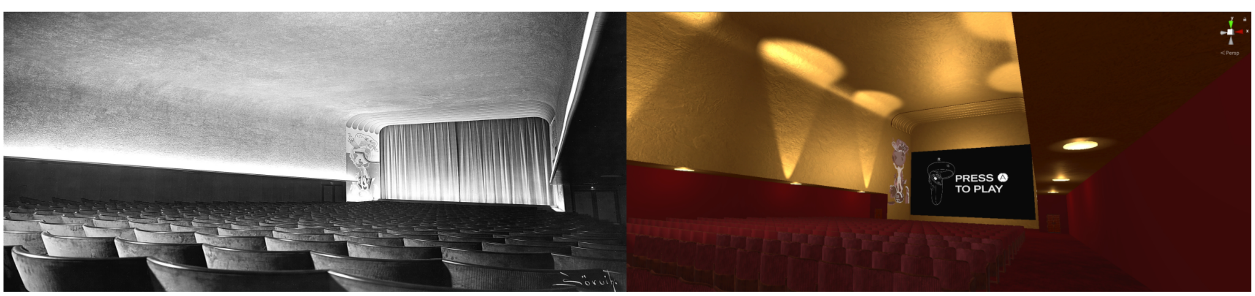

Figure 14. Auditorium: Screenshot of Game Compared to Photo Evidence
(Source: Obtained photographs from my academic supervisor with screenshots taken from Unity)

In order to get access to the auditorium room, the player first has to purchase a movie ticket at the cashier, then give it to the ticket usher waiting upstairs. If the player attempts to go through the passage doors without a valid ticket, s/he would not succeed since those are scripted using the `RigidbodyContrains.FreezeRotation` condition to imitate the locked state until the ticket has been shown. *Audiovisual goal indicators* are implemented in the forms of talking NPC and pop up texts to guide through the player in the process of gaining access. The `Lobby Scene` has a railroaded runtime direction embedded in the game mechanics. The first task is to meet with the cashier to buy a ticket. Upon doing so a ticket *resource* gets *spawned*. As. Next, the player has to carry the ticket to the ticket usher upstairs, then when it is prompted, it must be placed in his hand. Alternative flow is executed when the player has not bought a ticket, thereby the ticket usher refuses giving access. Nevertheless, the player has the privilege to interrupt these events any time by simply walking away from the NPCs as those are placed into trigger zones and are scripted to track the status, thus their behaviour is looped till certain conditions are met.

7.3.2) Quality of Reconstructed Elements

Reconstructed Element	**Reconstruction Quality**
The interior of the lobby and the auditorium room	The two most notably public areas were adequately reconstructed for the ability to explore the Flamman. These are the entrance and leather doors, the curved windows, ticket booth of the lobby; tip-up chairs, painting and the decorated arch of the auditorium room. The rooms are architecturally correct compared to the blueprints and photographs.
Movie ticket	Obtained by fictional purchasement, yet provides an immersive experience as the ticket can be grabbed by the virtual hands and be carried around. The ticket visualizes a once existent movie ticket which was photographed.
Cashier and Ticket Usher NPCs	Provides realism to the cinema simulation experienced in the mechanics of buying and showing the ticket. The appearance of the NPCs are rather digital than realistic which regards their skin, hair, and lip movement while talking. There were more details put on their outfit texture and body gestures.
Watch a movie	A video player is successfully implemented on a canvas under the characteristic arch of the auditorium room. On the other hand, the film screening is not a scheduled event as in real life, thus it is currently controllable for testing purposes and can be started with a button press. On the other hand, turning off the lights and darkening the room upon the start of the movie is implemented with solutions using optimization techniques.
Interactive doors and chairs	Provides immersive experience since rather than using animations, these elements are based on physics, therefore the virtual hand can push / grab / hold these. This provides the sensation of realism, thus these objects could be handled the same way as in real life.
Mediation of 1950	Vintage elements as just as once existent movie posters, a Swedish tram from 1956 passing by the building, the vintage uniform and body language of the cinema staff NPCs, and playing a famous American sci-fi movie (Forbidden Planet) were inbuilt well enough

	that the play testers could identify the decade of which the simulation takes place correctly.
Spatial SFX	Background music of the 50's added the `Start Scene` and the `Lobby Scene` of those that were typically played in elevator / longu in the past. Other sound effects just as the passing old tram that is ringing and the creaking sound to the doors are implemented as well. All of the sound effects are stereo and spatialized in 360 and using the bypass effect which all together provides the ability to hear as in real life.
Realistic player control	Next to the hand tracking feature, by the 6DOF sensors, the player is able to see height and orientation changes that can be made with the controllers and also by turning the head / body and seating / crouching down in real life while standing in the invisible guardian (setup play area with Oculus prior to the start of the simulator). `Avatar mode` provides more awareness of this by the definition of inverse kinematics, thus the player has the privilege to see his/her own limbs bending at the joints in real-time. Thereby, when the player sits down in real life to an armchair while taking a seat in the simulator can be a fully experienced physical action.
Scent of popcorn	Sensory element just like smelling the scent of popcorn cannot be done in any digital/virtual simulation since the headset is not capable of emitting aromas. However, people can have freshly made popcorn near them while being in the simulation.
Sensing temperature	Similarly to the previous solution, it is possible to sense the temperature of the cinema's auditoriums, which should be cooler than outside due to the ventilation. Small details that perhaps not many would notice when trying the simulation, however playing the simulator while being in an airconditioned room or by using a distant fan could raise the aesthetics of the cinema experience.

Table 8. List of Reconstructed Elements
(Source: Personal collection)

7.3.3) Unreconstructed Elements

Unreconstructed Element	**Reason and Effect**
Other rooms than lobby and auditorium	Some of the considerable public areas such as the restrooms were excluded from the reconstruction due to missing photographic documentation. The cinema building was not fully reconstructed, and the exploration became limited to the two rooms as a result.
Open world game	Rooms are separated into different game scenes due to the performance optimization. Load scenes at trigger points (invisible trigger zones behind doors) break the free exploration. The player experiences the loading of the next scene as a blackout that lasts for two seconds which emphasises the aesthetics of digitalism.
Visitor NPCs / multiplayer game	Due to time constraints of this project, visitor NPCs or other players were excluded from the prototype. This prevented the sense of togetherness while it should be a crucial element to the proper simulation of the auditorium room especially.
Visual disturbance by others while watching a movie	Due to missing the previous element (other visitors), the simulation excludes the situation of people - who are sitting in front of the player - to block the view. This would be another crucial element in the authentic representation of the cinema which in case of the multiplayer mode, could bring more realism to the simulation. Such as, if a player is moving the joystick up to the air, his virtual arms would be blocking the view for another player just as in real life.
Voice chat	Voice chat is excluded due to the game not supporting multiplayer mode currently. Voice chat should be featured in the `Lobby Scene` which would significantly raise the realism. While the voice chat could be an excellent tool to warn others when blocking the view, this feature should be disabled in in the `Auditorium Scene` in order to avoid giving chance for misbehaving players who would use the chat for shouting impolite words, and use voice chat for sabotaging the watching of the movie.

Table 9. List of Unreconstructed Elements
(Source: Personal collection)

7.4) Thematic Analysis Results

7.4.1) Participants

Five people in total agreed to be test subjects of this research knowing that their participation in the session (play testing and interview) requires physical presence during the time of the ongoing pandemic. Following the obligations in respect of CODIV-19, I have made verbal contractual agreements with each of the participants regarding the meeting location and the use of protective gear. The participants were males in their 30s to 40s. One UX/UI developer from the IT industry with the competency of working with mobile platforms and users on enterprise level; three developers from the video game industry with professional experience in working with various game engines other than their own, including Unity amongst others; and one academic lecturer in the Game Design and Technology MSc program with his scholarly work with the main focus on accessibility of games, moreover he has high technological knowledge in the development of augmented reality and virtual reality.

7.4.2) Play Test Observations

Note that participants are denoted by unique IDs as "*Pn*" due to the obligation regarding their anonymity stated in the consent form.

- **Observed P1:** Finds Start Scene too big. Grabbed ticket with no problem, ticket handled with no problem, clothing texture is good, looks real. Feels "*empty*" in the transition zone. Notice the low texture quality in the Auditorium. Giggles when discovered grabbing the chairs works. No projector objects for spot lights! Those need meshes. Started the movie and thinks the scene is dark.Complains on pressure on head due to headset already. Particle system light from the projection room looks nice. Avatar mode: Hands are too big and weird, orientation is weird. Harder to open the door. Want to see reflections of myself. Walking is slow, zero gravity ticket drop. Feels tall. Walk speed is slow. Participant is engaged in watching the movie now. The video is a bit laggy.
- **Observed P2:** Start Scene: Walk around and hear the music is spatial. Check the cinema picture. Hands mode: Find the outside realistic, with the lights and the tram that is coming. Opens the door without problem. Walks to the ticket boot and purchases a ticket. He passes the ticket from hand to hand and says: *"That's nice that I can do this, not like in other games where you have one hand for grabbing only"*. Then carries it upstairs without problem and gives it to the usher. Explores the corridor a bit, and sits down on the sofa in real life while taking a seat in the game on the corridor. Says *"I will wait a bit before going in for the movie"*. Then stands up and walks through the door, entering the Auditorium Scene. Auditorium Scene: Walks around and inspects the ceiling arch and the painting, then saiys: "The arch is so realistic, but the painting looks a bit funny". Walks to the chair and tries to grab it naturally. Amazed that those can be moved. Sits down by himself again in real life and looks around, then says *"Will there be people coming or it's just gonna be me?"*. Then told to start the movie. Movie played without a problem, finished playing and told him to switch to avatar mode. Avatar Mode: Repeats the steps without

problem, notes that it is much better to have a body. Tries to take the seat again right at the corridor in the lobby and notes *"I can see that I'm seated now, I can see my legs"*. Walks into the Auditorium Scene and moves the chair then notes "*Yes, and I can see that my arms are bending correctly, this is very immersive now"*.

- **Observed P3:** Start Scene: Likes the pictures of the controller mapping and inspects the cinema picture. Picks the Hands mode as told. Lobby Hands Mode: Sees and hears the tram coming, and says: *"I saw the railways on the picture in the start"*, forgot the grab button and repeatedly tries the trigger button to open the door. He is told which button to use for grab, he opens the entrance door with two hands and says "That's so real". Walks into the lobby. First, go to the ticket booth and without a problem, buy a ticket. Carried the ticket to the usher without problem. Went through the door and entered the Auditorium. In the auditorium, he walked to the front and looked around at the ceiling, then turned towards the chairs, walked closer, then said: *"The chair's texture doesn't look that good"*. Still remembering which one is the grab, he tried to grab the chair which worked, and said *"I can put them down for real, that"s awesome"*. The participant is told by me to take a seat on the sofa then start the move. He said " I can even smell the popcorn!". Playtester found the movie clear and fun, just short. He would have watched for longer if he could. Then he is told to select the Avatar Mode. Avatar Mode: He said *"I have arms and legs"*. Remembered everything from the first test and repeated without problem. Then he said, *"I had a seat number on my ticket, but the chairs do not have one"*.
- **Observed P4:** Start scene: posters look good, thematic. Lobby: Finds the door very immersive. Trying to grab the ticket. Checks where the further door leads to upstairs - a true explorer. Finds the trigger zone dark. Entered the Auditorium: Pressed the button to start without my permission, then said *"all went dark don't know what to click"*. He says *"Feels like being in the cinema"*. Finds the quality of the movie great and watchable. Problems: Guard shows up in his case when sitting down in real life. Have to sit unnaturally to hide the hands when seated in real life (on a sofa where you cannot hang the hands down). Switched to Avatar Mode and the game glitched because he did not stand up from the chair when loaded the other mode, and the guardian got re-anchored to a new height. He expected even more intractable little things, like push off paintings etc, crack the cashier's window.
- **Observed P5:** Start Scene: Inspects the pictures of the controller mapping and actually recognizes the cinema on the picture, then says "*I know this place, I lived around here"*. Then picks the Hands mode as told. Lobby Hands Mode: Sees and hears the tram coming, and says: *"I used to take the tram from here also"*. He opens the entrance door without problem. First inspects the lobby then keeps staring at the ticket usher upstairs. Decides to walk up on the stairs first without buying a ticket to see what happens. He is amazed at the body gestures of the ticket usher and says *"Oh, he looks so polite"*. Then walks through the hall and tries to open the door which is locked. Understands that he has to buy a ticket - he walks back

downstairs and says *"I think I should buy a ticket first"*. Walks to the ticket boot and without a problem, buys a ticket. Carried the ticket to the usher without problem. Went through the door and found the trigger zone dark. The Auditorium loaded. In the auditorium, he said:"*So this is what's inside here, I never knew it's so big inside"*. Then he walked between the chairs and noticed that they could be grabbed. Went around and put down a lot of them for fun. He was told to take a seat on the sofa in real life and start the movie. He said while seated- *"It's so real, except that I'm alone here, but I know this is just a prototype"*. Told to switch mode to Avatar Mode. Avatar Mode: He tried opening and closing the door several times while observing his elbow. He said *"I can see it's bending"*. Purchased the ticket without problem then when walking on the stairs he said: *"I can see my knees bending also, this is realistic"*

7.4.3) Interview Answers

The interview answers showed similarities between participants which together with the observations helped in the determination of common patterns during the thematic analysis. See interview answers table in Appendix C.

7.4.4) Summary of Thematic Analysis Results

Conditions	**During Simulation**	***Preferences***
[general tendency for motion sickness], [worn eyeglasses], [hungry during simulation], [caffeine in system]	[stable headset], [clear vision], [pressure on head], [experienced cybersickness during this simulator due: motion on curved staircase], [loneliness], [pressing the trigger button for grab]	[other visitors], [tolerates low quality textures and rather sticks to VR for immersiveness].

Table 10. Common Patterns Found During Thematic Analysis
(Source: Personal collection from participants)

Aspect subject to appraisal	**Evaluation**
Tendency for cybersickness in general	Varied between people who occasionally wear one of the VR headsets, and those who wear it on a regular basis. In both cases, the headsets are mounted for an average of 40 minute long duration. The participants claimed their tendency for experiencing motion sickness in general is attributable to the characteristics of VR and the type of application running.

Experienced cybersickness in Flamman simulator	Discomfort to the eye was enunciated, some with the statement that the occurrence of cybersickness symptoms such as slight disorientation could have been experienced in the Flamman simulator. The issue is attributable to the architectural characteristics of the building, such as the continuous turning with the thumbstick the play testers made when walking on the curved staircase in the `Lobby Scene` which was experienceable regardless of the chosen game mode. The experience of cybersickness differed between those people who have eaten a meal and those who were hungry and consumed caffeine-containing beverages. In the latter group, the disorientation lasted longer, which rarely followed by the sense of nausea in a few cases as reported by participants later on.
Comfort and vision	Some of the participants had worn eyeglasses, and all had worn face masks; the latter one was necessary due to the ongoing pandemic. Nonetheless, it was stated that the headset was stably mounted and the vision remained clear throughout the play test without any observed adjustments.
Sensation of physically being in the virtual environment	The sensation of physically being in the environment was predominantly experienced, rated highly immersive. However, it was difficult for some of the participants to abstract the simulation from virtual reality due to the pressure caused by the weight of the Oculus which dominated repression in this sensation. Regarding the movement capabilities within the simulation, there were no perceptible differences in comparison of game modes. Primarily, `Avatar Mode` was desirable preferentially over `Hands Mode` by reason of embodiment of a full body avatar, and the featured inverse kinematics regarding bending elbows and knees which potentially made the simulation more plausible in terms of realism.
Understanding and usability	Participants have asserted that the controller mapping was consistent and the goal indicators have assisted them in performing actions which were easy to understand. There were two issues however that was claimed. The first one is the grab functionality mapped with the controller's Axis1DPrimaryHandTrigger button that is located on the inner side on both controllers and supposed to be pressed by the middle finger. The claim has been made that their expectation was to press the Axis1DPrimaryIndexTrigger which is generally used in games for shooting. The other issue is the scene dividers which are trigger zones to make transition between scenes. These zones are implemented as small dark rooms behind the doors.

	Thereby, participants were quite hesitant walking through the doors in the Lobby Scene that led them to this darkness as observed during the play test.
Authenticity of realism	From the perspectives of actions and interaction, the simulator has received uniformly positive feedback when its aspect of realism has been subject to appraisal. This was regarding the realistic expectations of actions to do during the gameplay, which were valued as an eminently plausible lifelike experience; accountable to the following order of actions: (1) buying a movie ticket, (2) carrying the ticket, and eventually (3) placing it to the cinema usher's hand to gain access to the auditorium - otherwise facing with refusal. Additionally, the implemented physics based interaction form (interactive door handles and tip-up seats) as well contributed to the plausible gameplay. On the other hand, participants have pointed out the obvious differences in the texture quality between scenes. Regarding the graphics quality, the rated admissibility level of the textures and lighting quality was slightly diversified when the question of "whether the simulator looks rather realistic or digital" was asked. While some claimed that the NPCs look very digital, others said that the texture of their outfit looks realistic for instance. Mutual agreement was made upon the fact that the quality of chairs in the `Auditorium Scene` has low quality. Reassuringly, the participants have opined the digital look of the simulator rather as a tolerable performance optimization, and unanimously claimed their need for a VR system based simulation regardless of the promisingly ultra graphics that other platforms would be capable of. The reason for that is by the immersiveness and the haptics which are yet more preferred than ultra graphics.
Authenticity of the reconstructed Flamman	From the perspective of accuracy regarding the reconstruction quality of Flamman, the virtually explored prototype was unanimously rated as being identical to the inspected photographs. The mediation of the 1950's atmosphere of Flamman was as well successfully simulated throughout the vintage clues as told by the interviewees. Their impression was gained from the appearance of the cinema staff, such as their old fashioned uniform and the animated gentleman's body postures, moreover, the movie posters and the played movie which are convincingly self-evident. Ultimately, the general impression of the simulator was evaluated as being highly adequate for the exploration of the once existent counterpart by the accurate reconstruction of elements. The

	prototype suits the purpose of preserving the cultural heritage, in which the players are provided with the sensation of being visitors in an immersive virtual museum rather than just using a casual cinema simulator application. This latter statement is due to the fact that other visitors are not reconstructed in this prototype due to the time constraints. Knowing that the experienceable sensation of loneliness is factual, therefore I propose the future iteration to include pedestrian NPCs walking on the street, and the enrichment of the simulation by visitor NPCs lining up at the ticket booth and taking seats in the auditorium room.
Suggestions	Raise immersiveness by eliminating the use of controllers and put the hand tracking into use. Allow multiplayer more or create animated visitor NPCs as the audience is expected in a cinema.

Table 11. Thematic Analysis Results Summary
(Source: Personal collection from participants)

7.5) Validity Threats

Due to this project required time consuming effort to be put into the creation of 3D assets from scratch, thereby it lengthened the overall process of the game development which subsequently left a little time for the data gathering and analysis research activities. On the other hand, my competency in VR development can be considered as being on the beginner level, thus my priority aim was to make sure that the simulator runs smoothly on the headset that I own, the Oculus Quest 2 with the use of the Oculus Integration plugin. Thereby, reaching for participants was furthermore obstructed by this fact other than the pandemic. Due to that Oculus Quest 2 is perhaps an unaffordable gaming system for many people, or they are owners of another VR system, therefore I had no choice but to request and arrange physical meetings whereas they could borrow my headset for the play test. Ideally, the simulator should be cross-platform for various VR systems, thereby it would have been possible to reach more play testers from online communities and gather quantitative data via electronic surveys. I believe this research could benefit from the performance of a statistical data analysis in order to measure the relevance of findings from a more diverse group of people and prove the credibility of the data.

8. DISCUSSION

In this section, I discuss quality aspects along with choices and alternatives that are considerably influential to the immersiveness of a simulator that reconstructs a specific space and time.

8.1) Faithful Preservation of Historic and Cultural Heritage

Preciseness within the representation of historic and cultural heritage is a high requirement in games dominated by the *plausible* "*Loyalty To World*" of the MDF [21]. As this simulator is being dedicated for the exploration of the once existent Flamman experience which takes place in a specific time and space, therefore the importance was to work with elements convincingly correct for the mediation of these significant for the *simulationist* [1] people, e.g.: the users when playing the role of the visitor. The determination of what elements can be considered as convincingly correct and how should those be reconstructed requires preliminary research, in the form of searching and gathering relevant information. Generally, the availability of information depends on the historical or cultural significance of the selected reconstructable artifact, meaning that its significance determines quantity and quality of the documentation of evidence. Moreover, the information weakens the further we go back in chronology.

Chernobyl reactor and Pripyat city could be well reconstructed virtually as there is plenty of information available to work from. The designers could make use of architectural blueprints, photographs, information of employees, documentation of the court trials and witness accounts. Chernobyl VR Project [9] is therefore very authentic. Unfortunately, this information level of details is unavailable in the case of Flamman as it cannot be considered historically and culturally important. That is due to the fact that there were no significant events to be registered within the cinema that would have been worth to remember, therefore is why the Flamman is not as famous as for instance the architecture of the Titanic due to its tragedy.

The photographic documentations were available in the case of Flamman, however those were made in two different decades. The 1935's vintage photos are black and white capturing the exterior of the building from two angles; moreover four interior photos from which two are made in the lobby, and the other two in the auditorium room. The other set of pictures are color photographs taken in 2019 from various angles. Nevertheless, those captured the same rooms just as the vintage ones. This means 84 years of differentiation between the photographs, obviously with changes made in between this duration since the Flamman cinema was transformed, for instance, its most iconic room - the auditorium room - had been changed to a sermon preaching hall to support the current function of the Flamman building. Benchmarking elements were therefore based on the vintage photos which lacked information regarding the colors and materials, thereby those could be reconstructed as textureless 3D models at first. On the other hand, the modern pictures indicated some of the unchanged elements such as the staircase and the cinema chairs, therefore their textures and colors could be obtained from those. The interior design regarding the materials of the floors and walls could be obtained from the small blog article [50], which is the only remaining source describing the Flamman cinema. Also note that these photographs and the descriptive article all together is a documentation of the lobby and the auditorium rooms solely. According to the architectural blueprints, there are more rooms in the Flamman which have not been described, therefore those became non-reconstructable parts. This issue did not ruin the simulation as the well-documented rooms are the two most public rooms, adequate enough to represent the Flamman cinema, however it limits the explorability. Next to the reconstructed building and functionality, additional historic and cultural clues should be included to enrich the experience accurately to the environment and time in which the simulation takes place. These details could be regarding the appearance and behaviour of the game characters, sound effects, music and other decorative elements. In the case of Flamman, clues can be found in the uniform and body gestures of the cinema workers, the movie posters, the played movie, the music of the lobby, and a circulating old Swedish tram around the building.

The game Sid Meier's Civilization [7] successfully represents different cultures through pop up windows visualizing the appearance of leaders of different nations, all of which are speaking with a specific accent. In the case of Flamman the cinema usher's behaviour and uniform were not documented, therefore this uncertainty required research of cinema workers' appearance in the decade of 50's which was done by browsing the internet using keywords such as "50's", "movie usher", "uniform". The results indicated the typical old fashioned fabric jacket uniforms with double sided buttons on the torso, similar to the military uniforms of the 1856's Austria-Hungarian Gyulai regiment and to the 1865's British Fusiliers. Moreover, the cinema ushers on the illustrations that I found were posing straight with one hand behind the waist which is a formal posture of standing by. My assumption was that this gentleman's body language is generally true to this era, typical to hospitality industrial workers such as hotel staff members or restaurant waiters for instance. Therefore, the cinema workers in the Flamman simulation are designed to wear this old fashioned cinema usher uniform and are animated in a polite manner when talking to the player.

The authenticity regarding the reconstruction or events that took place in the cinema could not be strongly verified due to missing evidence which I stated is attributable to the fact that the Flamman building is historically and culturally insignificant in the sense that there was no tragedy or anything remarkable that happened there. Unlike in the case of Chernobyl VR Project [9] in which even voice interviews of witness accounts could be included within the gameplay, thereby the user can get to know what were the profession of people, what did they wear and what happened to them. Interviews with people who used to attend the Flamman back in 1950 cannot be identified, there are no records of the visitor's list. Therefore, visitor NPCs and what and their behaviour could not be reconstructed, secondarily I stated that it was due to the time constraints of this project. Designing masses of NPCs would be time consuming considering that they all should have the appearance of the time of 50's, on the other hand, they should have some level of AI so that they would queue up at the ticket booth, hand over their ticket to the cinema usher and occupy seats in the auditorium room. The other option would be to make the simulator multiplayer, and give the "Character Creation Responsibility" [21] to the player who could select from a variety of pre-designed hairstyles and clothes of the 50's similarly to the Mafia [8] game series. Ultimately, the lack of visitors or other players within the gameplay of Flamman simulator had a negative impact on the authenticity of realism, such as the play tester's expectation was to meet with masses of other people attributable to the cinema going experience.

8.2) Realistic Simulation: Graphical Realism

The aim should be to create a realistic representation of the real world, however, this aspect is not set in stone. The reconstructed history and culture can be represented in a gamified, somewhat fictitious environment as in the case of Sid Meier's Civilization [7] where the world map is both cartographically and geographically fictitious; moreover, the different nations are randomly scattered disregarding their migration history. Nevertheless, it is easy for the "*simulationist*" person to find fan-made contents online including the "real world map". Perspicacity of graphical surrealism manifested in The Sims 4 which is a life simulation video game tailored for the young target user group, therefore the game has an overall simplified and smooth digital look. The game objects are made of simple polygons and mostly textured with colors only, in as much as the hair of the sims (humanoid game characters) appears to be soft plastic for instance. Design choices regarding the surrealistic graphics are as well attributable to the need of performance optimization, thereby the game can run on the older machines likewise. Other than missing objects from the game, custom content makers provide a large variety of ultra realistic looking counterparts of inter alia, hairstyles, facial hair, body hair, skin re-texture, clothing, as well as the possibility to download higher fidelity furniture sets to comply with the user's need of realism. In the case of Flamman, graphical realism is very important as it is dedicated to the virtual reconstruction of a real-life existent building to be explored immersively, therefore this experience must be as authentic as possible. Meaning that the virtually reconstructed counterpart of the same environment shall appear to be photorealistic.

Creating high fidelity meshes and textures requires deep knowledge of the reconstructable artefact and prerequisites high competency in using one of the 3D modeling softwares. In case the target is somewhat intact, entire environments or parts of it can be photogrametrically [10] scanned which unburdains the modeling and texturing process just as it was utilized in the Chernobyl VR Project[9]. Photogrammetric scanning could not be used for the Flamman due to the changes made to its interior throughout its transformation to church, nor to generate 3D models of the remaining photographic evidence due to the inadequate quantity and quality of those. Based on these reasons, the reconstruction of the Flamman meant manual modeling from architectural drawings, black and white photos and the utilization of other online sources to find out what materials were used. On the other hand, the building is relatively simple, its modernity was also noted by the blog article [50] therefore its modeling was relatively uncomplicated and rapid. The level of difficulty depends on the complexity of shape and detail of the modelable artifact. For instance, the difficulty rises when modeling buildings and interiors that are built and decorated according to complex architectural styles such as the Georgian, Baroque, Elizabethian, Chinese style. In these latter cases, there would be plentiful decorative features to be modeled separately before combining those to one final mesh, often unique parts compared to each other, such as miniature roof sculptures as in the case of the Chinese architectural style for example. It is possible to make a flat mesh rendering a detailed image texture and distantly place it somewhere to the background, otherwise the provision of such should be avoided if the player can observe those from close range.

In this project, development experiments with Unity took place to conclude the maximum graphical quality that can be run on the target platform, Oculus Quest 2. These were addressing various implementation techniques for creating high definition lights, shadows and textures. For high plausibility, effort should be put on creating a graphically detailed virtual environment that could faithfully represent the real world by addressing textures to detail objects and combine different light types for the proper scene illumination. As well as to include details in high definition to let the user visually understand the environmental conditions. For instance, buildings of Pripyat have overgrown vegetation and shards of glass can be seen everywhere in the Chernobyl VR Project [9] which are all manual additions for the faithful representation of abandonment, emphasising the aftermath of a disaster. The reference photographs used in the Flamman project suggest that the building was a seemingly neat environment. The walls and floors are kept in good condition throughout the decades as there are no signs of erosion which could be seen right now. However, there is no documentation regarding renovations history that took place, therefore the building in this simulator is restored in its full splendor. On the other hand, the simulation takes place 10 years after the opening time of the cinema, therefore the environment must be alive rather than significantly eroded, moreover, the building has never been abandoned, only transformed. Other types of details were considered for the Flamman, such as popcorn on the floor in the auditorium room. However, no information was found about what type of snacks were taken to the movies, or whether there was any, therefore the idea of filthiness as a potential detail has been skipped.

The remaining task was to make objects appear to be real; for instance, the lights should have different tones and intensitivity, and those must be reflected back from smooth surfaces, mattness should be defined for the velvet seat covers and transparency material loaded for the windows. Moreover, textures should have a detailed surface and depth instead (bump map) of rendering single color 2D images. Thus it is important to make use of normal map and height map per texture material to give it a depth. The materials of objects to be seen from close range (e.g.: the player walks to it) therefore must render (a) high definition image(s).

8.3) Game Performance

Several attempts were tested to raise the simulator's graphical realism, and the possible solutions were identified that are listed in section 6.2) Development Experiments. The simulator's resulting performance was highly affected by the lag, sub-categorically attributable to the high definition of lights and textures that were dramatically reduced in terms of quality. Additionally, the number of objects to be displayed at once such as the hundreds of cinema chairs were computationally heavy for the Oculus Quest 2. Ultimately, the remedy was to use the performance optimization techniques stated in 7.1.2) Performance Optimization *(PO_1: Removal of Particle Systems, PO_2: Switch From Realtime to Baked Lights, PO_3: LOD Groups and Downgraded Quality of Textures, PO_4: Occlusion Culling).* As an aftermath, graphical dullness of colors, textures, shadows and lights became characteristics of the auditorium room.

In general, continuous gameplay lag is less tolerated than not having HD graphics. In the research by Tseng et.al. [66], participants were surveyed to measure their reaction to lag in video games. The majority of players tolerated the presence of lag, most of them tried to resolve the issue by restarting the game, however, the tendency of quitting the particular game in case of continuous lag was notably the end result. Participants of this research did not experience lag as the prototype was already optimized prior to play test sessions, however they were exposed to the resulting graphical quality which they noted to be low. Nevertheless, they rather use VR and tolerate its low graphics than using another non-VR gaming platform which would likely reduce the level of immersiveness.

The GPU of Oculus Quest 2 is capable of rendering high definition graphics clearly, however its CPU underperforms indeed [13], considerably due to being an untethered device. The problem manifested in the rendering of a variety of textures for large quantities of game objects which remained an issue in this project, although the ASTC compression method suggested by Gabor Szauer [14] was used. This brings up a question whether other VR devices that are tethered would perform better than Oculus Quest 2. Perhaps not in this case, since the overwhelming number of cinema chairs and lighting would be computationally devastating for those devices as well without the use of performance optimization. The Flamman cinema has a simplified appearance in reality which is why the ease of modeling was the case. In alternative cases when the reconstructable building is one of the complex architectural styles it would potentially mean significantly more computational tasks by the amount of elements and their details that would be difficult to endure for the VR systems in general. For instance, richly decorated rooms with various materials and patterns would be more performance heavy due to the rendering of metallic and reflective surfaces such as gold, moreover, need to consider that the variety of patterns that are often used in complex styles would result in more draw calls per textures rendered to the objects.

8.4) Realistic Simulation: Physical Realism

3 dimensional virtual environments that ignore unnatural and fictitious elements can be categorized under those that are designed with the “360 illusion” dominance set for the “Environment” fader as defined by Stenros et.al [21]. A realistic simulator should use this fader setting if the virtual environment is a reconstruction of a once existent or still existing place in real life, especially if the ”Loyalty to World” fader is set to be highly plausible. These faders together logically define the requirement for creating realistic player character attributes and controls, however this aspect is not set in stone. For instance, the environment could be realistic, but the player could float around or teleport in it. Nevertheless, real life humanoid abilities are important to consider for the realistic role play in this case, as it would provide a plausible engagement value for the *simulationist* people as described by Ron Edrawds [1]. Therefore, the Flamman simulator was implemented based on these faders.

Since VR has the potential to offer rich sensory experience as Burdea [2] pointed out, the “thin character” for the “Character as Mask” fader can be intensively structured by making the user embody the player character and set the camera to first person perspective. Thereby, the camera becomes the eyes of the user and if the controllers are mapped to the corresponding hands correctly, then this setup provides the sensation of self-awareness of being in the virtual environment, which is especially plausible if the virtual environment is ultra realistic both in graphics and physics. Oculus Integration plugin was used in this project that offers pre-made virtual hands. The problem with this prefab is that the avatar does not have any other body parts than the hands, therefore this implementation cannot be truly considered as a "thin character" despite that those are humanoid hands. Similar implementation can be found in the Bigscreen application [12] whereas the avatars are composed of head and torso with hands, but no arms or legs.

On account of increasing immersiveness in the Flamman simulator, "thin character" was supported with the implementation of a full body avatar, called the Avatar Mode that features inverse kinematics. In other circumstances, if there would be an option to faithfully represent the user, then the user should be offered to scan himself and become reconstructed in 3D similarly as in the case of the photogrammetrical [10] scanning and model generation of real life objects. The privilege of embodying the player avatar with VR opens up possibilities in the definition of interaction forms unlike it is experienceable by any other gaming consoles, supported by the inbuilt sensors for tracking the movements of the head and controllers.

These sensor datas are then utilized to perform physics-based interactions within the simulator. For instance when grabbing an object, it is required to move the hands and reach the object instead of pressing a button alone. Moreover, the game objects are not pre-animated, thus they have weight and are considered as rigid bodies to be handled as in real life. The doors in this game are operating as saloon doors using invisible hinge joints with defined springiness, thus it slows down in its movement according to the law of inertia, eventually coming to a complete stop as expected in the case of saloon door physics. Moreover, the door handles can be grabbed, both doors at the same time with the possibility to hold them in position or open and close them which is an advantage over the animation based interaction forms that would be harmful for the immersiveness. Distance grabbing and teleportation abilities were purposefully not implemented in this simulator for obeying the aspects of reality mentioned above. Nevertheless, walking in the game does not require the user to walk, instead it is based on user input by controllers. As a compensation to this, immersiveness is preserved by the featured inverse kinematics, thereby the user can see the bending of joints of the avatar. The level of immersiveness was highly appreciated by participants in as much as they persisted in the idea of using a VR system despite the simulator's resulting graphical reality compared to as if it would be platformed on a computer.

8.5) Caution design for VR

Motion sickness or cybersickness in virtual environment (VE) is a phenomenon usually triggered by, inter alia, the unsynchronized motion to the visual stimuli, having a too small or too large FOV, blurry or too bright environments. On the other hand, disorientation and cybersickness is a tendency that varies between people and related to the individual's vestibular system and current condition that could be a temporary condition or permanent, therefore cybersickness cannot be 100% eliminated for everyone. Moreover, the characteristics of the VR headset can also be the causal factor itself.

To understand motion sickness better, it is similar to the case when a person sits too close to the television while watching an action movie. The discomfort occurs due to the entire field of view being under motion while the person is still, the screen is bright and flashing, moveover the pixels are blurry from this range. Therefore, the vestibular and visual systems get messed up which creates the sensation of disbalance and disorientation, the consequences of these are the symptoms identified by LaViola [4]: *(1) eye strain, (2) headache, (3) pallor, (4) sweating, (5) dryness of mouth, (6) fullness of stomach, (7) disorientation, (8) vertigo, (9) ataxia, (10) nausea, (11) vomiting*. The weight of the headset is another causal factor of discomfort. Oculus Quest 2 has a mass of 503 g (17.7 oz) therefore it is considered lightweight compared to other VR devices. However, this weight is not distributed on the top of the head that one can bear durably. Instead, the pressure can be sensed on the facial bones around the eyebrow and nose, additionally on the cervical vertebrae of the neck also, mostly when bending the head.

There are several motion sickness reduction techniques suggested by LaViola [4] that could possibly connect the human more physically to the VE. However, the budget and time scope of this project was inadequate to carry out the cybersickness reduction ideas such as the motion platform and direct vestibular stimulation. For this reason, the development experiments regarding cautious design for motion sickness were dedicated to the design and implementation techniques addressing the brightness, definition of motion, and FOV reduction in VE [5, 6, 54, 55]. Moreover, to find solutions to incorporate those into the Flamman simulator in a compatible way to the Oculus Integration plugin within Unity. The results of these are described in section 6.2) Development Experiments.

Design choices took place regarding the scene lights in Unity which became slightly dimmed for the sake of the eyes. Unlike the struggles for implementing high graphical realism which was challenging due to the requirements of the Oculus Integration plugin [51], this plugin itself unburdened the way of deploying motion sickness reductor techniques through the provided scripts that defines the player's movement and the cameras for the eyes. It was straightforward to access the properties of those scripts and change the values for the variables, such as defining new clipping planes for the cameras to reduce the FOV, and experiment with different character controller values till I reached the desired player behaviour. For instance, walking is defined in a continuous translation composed of small units that is the closest imitation of a step range synchronized with the animation and the definition of smooth turns with the thumbstick, both are defined at a comfortable speed to the eyes. Snap turn and teleportation that are often the type of movements in other VR games were not considered for the player of Flamman simulator as those would violate the sensation of physical realism. The other reason for their enclosure was due to the likelihood of triggering motion sickness symptoms such as disbalance and disorientation. Nevertheless, cybersickness is triggerable by a human factor that is attributable to the phenomenon of how people naturally freeze their gaze at a direction while turning. Cybersickness by this phenomenon can be experienced in the Flamman simulator due to the architectural structure of the staircase which is curved (spiral), thereby causing people to look ahead while maneuvering with the controllers to keep the desired direction of gazing point. This is an indication that those virtual environments that are structuring many curved pathways would likely lead to nausea.

8.6) Realistic Simulation: Realistic Gameplay

Video in the Flamman cinema simulator is intentionally disallowed to be played from external sources such as from YouTube. It would be unrealistic to have freedom of choice to pick a movie from an infinite variety, and picking a modern one could violate the mixing desk of fader *plausibility* of "Loyalty to World" [21]. On the other hand, the browsing would require the user input on YouTube's interface appearing on the movie canvas when browsing. Such should be eliminated in realistic simulators, unless making a content aggregator to retrieve data from YouTube and parse the data in a representation in which the UI is made to look like being part of the old fashioned VR environment. The other issue with playing videos from external sources would be the presence of advertisements. Not being logged in or having a free user account on YouTube means that the user must watch a short ad at the beginning of each video which can be skipped after a couple of seconds, nevertheless, most videos have multiple ads embedded within the duration of the video. Filtering the ads through the aggregation process is possible, however that would violate the terms of use of YouTube. In different circumstances, the designer's choice could be to make use of the "pay for no ads" in the Flamman simulation, consequently that would mean an intentionally created monetary dark pattern [24]. Yet, it would violate the realism of the simulation since a visitor of a cinema should only be able to pick a movie when buying a ticket, thus in this simulator the user can fictively purchase one at the ticket booth from a staff member in the lobby.

Currently, the simulator is a prototype which excludes visitor NPCs or other players from the gameplay due to the reasons mentioned above related to the time constraints and difficulties in the design of masses of characters or the implementation of customizability (character creation responsibility) in case of multiplayer. As a result, participants have noted that they felt lonely which is due to the unstructured *multiplayer game* design pattern [25, 65] hindered the instantiation of *social interaction*, subsequently the sense of *togetherness* that players could feel if they would be queuing up at the ticket booth, and sit around each other in the auditorium. On the other hand, it is questionable whether queuing at the ticket booth would be beneficial for the realistic simulation indeed, or such phenomenome would lead to the grinding dark pattern [24], after all, there could be hundreds of players in the session at a time, concurrently trying to buy tickets obstructing each other.

Multiplayer mode would bring another issue to be solved regarding the movie event in the auditorium room since it would be impossible to guarantee the continuously large number of players expected for the sensation of the cinema atmosphere.There would be hundreds of empty seats which could be filled with generated bots (visitor NPCs) - as many as needed. The root of the problem would be attributable to the issue that only a few people at a time would join the same movie event, others would potentially wait for another movie of their interest. The possible solution could be to support every user concurrently on the server by displaying the content of the canvas object locally for every user. Thereby, the same canvas should play different movies for everyone in the session. From the player's perspective, s/he would be able to see others but not knowing they are watching different movies. Since different movies have different duration, the current implementation regarding the switching lights on and off (darkening the room) that is tied to the length of the video must be changed. To address this, the baked lightmap data should be shared with everyone which is the room's default illumination, however the darkening must be displayed locally as well just as the canvas content. That would support the *drop in* and *drop out* [65] without disturbance, so the room lighting would not change every time another player starts and finishes watching a movie.

9. CONCLUSION

The aim of this project was to faithfully reconstruct the Flamman cinema theatre of Gothenburg in 1950 so that it is explorable in virtual reality with the Oculus Quest 2 VR system. The reconstruction was carried out with Blender modeling software and the simulation was developed using Unity game engine with the Oculus Integration plugin. This prototype was designed and developed to fulfil another goal, that was the delivery of a highly immersive experience to the user.

The research began with the investigation of the first sub-research question such as "*What design elements are relevant to create a highly plausible simulation of a particular time and space?* ". The answer to this was gathered under quality aspects compositional to the provision of the plausible experience, such as *faithful preservation of historic and cultural heritage, graphical realism, physical realism,* and *realistic gameplay*. Moreover, the incorporation of *cautious design for VR* to avoid cybersickness, and game development methods including *performance optimization techniques* to ensure the smooth running of the simulator tailored for the chosen headset. Considering these quality aspects being objectives to this particular simulator, the goal was to conduct an action research in order to find answers to the main research question which was "*What are the influential factors on quality in the reconstruction of the Flamman experience?"*. Therefore, the development phases were dedicated to support the quality aspects together with development experiments that resulted in identification of influential factors and the delivery of an immersive simulator in a quality endurable for the Oculus Quest 2. The answer to the main research question is the following influential factors on quality: *(f1) information availability*, *(f2) architectural complexity*, *(f3) technological affordances*, *(f4) game performance optimization*, and *(f5) definition of player in VE*.

By following the completion of the development, thematic analysis was carried out to probe the quality of the simulator's authenticity, identicality and immersiveness. The Flamman simulator has been evaluated by participants under play testing sessions and interviews. Ultimately, their qualitative feedback was utilized in the thematic analysis to answer the final sub-research question which was the following: "*What is the resulting satisfactory level regarding the overall simulator, and why?*".

The reconstruction of the Flamman cinema theatre regarding the mediated aesthetics of time and space was highly determinant by the fewness and incompleteness of the remaining photographic evidence which restrained the explorable areas of the building within the prototypic simulator, consisting of the lobby and the auditorium room exclusively. Notwithstanding the meager exploratoribility, these rooms were the most publicly accessible and commonly visited areas of the cinema, therefore the availability of those can be considered adequate enough to represent the Flamman cinema solely. The interior of these rooms have been evaluated by the participants who have found very high identicality between the virtual equivalents compared to the real life counterparts during the inspection of the photographs that were used for the reconstruction. The supposition that virtual reality is eminently potential to offer rich sensory experience has proven to be veridical in the provision of perceiving haptics and the immersion of players inside the digital world. However, this sensation is imperfect when it comes to the plausible simulation of the atmosphere regarding the authenticity of realism. This imperfection is identified to be attributable to the following influential factors.

Sensation of discomfort is generally attributable to the pressure on the face caused by wearing VR headsets which are required to be mounted very tight to ensure its stability. The default strap that comes with the headset usually loses stability little by little due to the weight of the headset, and can be an immediate consequence of sudden head movements. The Oculus Quest 2 that participants have worn was mounted with the elite strap which did not eliminate the pressure completely, however reduced it while also ensured the stability conspicuously well as none of them were seen adjusting the headset during gameplay. On the other hand, discomfort due to motion sickness is another side effect of VR in general, mainly dependent on the definition of motion and visual effects within the virtual world. The occurrence of discomfort is also specific to the tendency or diathesis which varies among people. Moreover its intensity and durability could be dependent on current needs such as hunger or the presence of caffeine in the body therewithal. Such could not be eliminated to the extent of absolutiness in this prototypic simulator, however, I could reduce the occurrence of cybersickness symptoms by the incorporation of methods dedicated to the cautious design for motion sickness. Despite my commitment effort to the cautious design, the simulator must have been compiled to the architectural blueprints which outlines the installation of a curved staircase as being the only passageway to the auditorium room accessible from the lobby. Therefore, players have no choice but to take their steps under the obedience to the laws of physics. This staircase was the causal factor of some slight discomfort as experienced by participants during the play test, attributable to the continuous turning they made in order to follow the curve of the staircase while trying to keep facing to the forward direction.

The main influential factor to the provision of the Flamman experience was concerning the reconstructible elements composable to the authentic atmosphere, just as the unreconstructable ones which were conditioned on technological affordances. This set boundaries to the possibilities and continuously opposed as an obstruction which subsequently shaped the overall quality. Compromises were made between graphical realism versus the performance quality due to the capabilities of Unity game engine and Oculus Quest 2, notably to the detriment of graphical quality predominantly. Concessions were made in favor of high performance by the sacrafication of the texture and lighting quality, even more so to the comprehensive application of performance optimization techniques. Contrary to this, VR seems to be one of the most optimal ways for the purpose of exploring virtual environments given by its sophisticated capabilities suitable to provide highly realistic interaction forms between the user versus digital objects. I was able to raise the simulator's immersiveness by the addition of realistic expectations of actions, physics based intractable objects, and by the implementation of game modes in which the full body avatar mode was more preferred due to the featured inverse kinematics. Ultimately, these characteristics improved the Flamman experience to the extent that users persisted in the idea of using the VR system for the exploration of the cinema despite the digital look.

Future work should be dedicated to this simulator by making it cross-platform between different VR systems, furthermore to complete the simulation with the addition of visitor NPCs with high AI level; and eventually release a multiplayer mode, thereby giving space to new opportunities to enrich the simulation hypothetically. For example, by avatar customization, queuing up at the ticket boot and attending a movie with others. Moreover, transform the simulator to a real functioning cinema by connecting the ticket purchasing to the online financial payment services and play scheduled movies in real time.

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Appendix A. Interview Questions

Q1. Get to know: if they have a tendency to have cybersickness in general:

Q1.1) Is this your first time wearing a VR headset?

Alt. Q1.1.1) How often do you wear one?

Alt. Q1.1.2) Approximately, how long do you wear it on average?

Alt. Q1.1.3) Did you ever experience motion sickness while wearing a VR headset?

Q1.2) Have you had a meal today? Are you hungry at the moment?

Q1.3) Have you consumed any beverage today containing caffeine such as cafe or tea?

Q2. Assessing possible influential factors: Oculus headset:

Q2.1) How was your comfort level while wearing the headset? Was it stable? Did you notice pain?

Q2.2) Was the vision clear or did it go blurry from time to times?

Q2.3) Did you feel any sort of sickness like dizziness, headache or nausea during the simulation?

Alt. Q2.3.1) When did the symptoms occur? Was it during a specific movement in the simulation or after you have removed the headset?

Alt. Q2.3.2) What were you doing exactly?

Q3. Assessing gameplay: understandability & usability:

Q3.1) On a scale of 1 to 5 where 5 is the best, how would you rate the learnability of the controls?

Q3.2) On a scale of 1 to 5, how would you rate the understandability of getting access to the auditorium room? How straightforward was it to figure out how to do that?

Q3.3) What is your impression regarding the movement when you played in Hands Mode and in Avatar Mode?

Q3.4) Which game mode do you prefer of the two when it comes to the interaction with the physical objects such as doors or seats? And why so?

Q4. Mediation of Flamman cinema experience:

Q4.1) Did you feel like you were physically in the building?

Q4.2) Which decade do you think you were in, and what elements convinced you about that?

(Showing real pictures of Flamman)

Q4.3) These are remaining photographs of the Flamman cinema. How identical was the interior of the simulation compared to these pictures? Do you think the cinema is reconstructed properly?

Q4.4) How would you evaluate the appearance of the simulator? Does it rather look realistic or digital? Why is that so?

Q4.5) Would you rather explore the cinema building on a computer if the graphics were significantly better than on the Oculus?

Q5. Open ended questions:

Q5.1) What is your overall impression regarding this simulator?

Q5.2) Do you have any suggestions for an improvement?

Appendix B. Consent Form

CHALMERS UNIVERSITY OF TECHNOLOGY | UNIVERSITY OF GOTHENBURG

Consent for participation in a research play test and interview

Flamman Cinema Simulator

I agree to participate in a research project led by Petra Béczi, from the University of Gothenburg, Game Design and Technology Msc. The purpose of this document is to specify the terms of my participation in the project through being observed and interviewed.

1. I agree to be observed during the play testing and interviewed for the purpose of the student assignment named above if that will not be video / audio recorded.
2. The purpose and nature of the interview has been explained to me.
3. Any questions that I asked about the purpose and nature of the play testing and interview have been answered to my satisfaction.
4. I have the right to interrupt the session if I feel uncomfortable in any way. I have the right to withdraw from the play testing and interview.
5. I have been given explicit guarantees that the researcher will not identify me by name in any reports using information obtained from this play testing and interview, and that my confidentiality as a participant in this study will remain secure.

Participant's Signature ______________________ Date ______________

Researcher's Signature ______________________ Date ______________

Appendix C. Interview Answers

Q#	Interview Questions	P1 Answers	P2 Answers	P3 Answers	P4 Answers	P5 Answers
1. Get to know: if other VR games are causing them cybersickness						
1.1	Is this your first time wearing a VR headset? (If not):	*False*	*True*	*False*	*False*	*False*
1.1.1	How often do you wear one?	*Few times a year*	-	*Weekends*	*Weekly*	*Couple of times a months*
1.1.2	Approximately, how long do you wear it on average?	*20-40 minutes*	-	*for hours, but taking breaks between*	*1-2 hours*	*20 to 60 minutes*
1.1.3	Did you ever experience motion sickness while wearing a VR headset?	*Yes*	*No*	*Yes*	*Yes*	*Yes*
1.2	Have you had a meal today? Are you hungry at the moment?	*Yes hungry*	*Yes, but slightly hungry*	*No*	*Yes had meal and not hungry*	*Haven't eaten, and hungry*
1.3	Have you consumed any beverage today containing caffeine such as cafe or tea?	*Yes,*	*Yes, coffee*	*Yes*	*Yes, quite a lot*	*Yes, tea*
1.4	Is s/he wearing eyeglasses?	True	False	True	True	False
2. Assessing possible influential factors: Oculus headset						
2.1	How was your comfort level while wearing the headset? Was it stable? Did you notice pain?	*Yes it was stable and noticed pain also. Not comfortable.*	*Yes, had minimal pain due to pressure*	*it was stable but it pushed my face*	*Pretty much comfortable, but very aware that it's on due to the pressure. Wearing for longer would be uncomfortable*	*Yes, I had pressure on my face, but not unbearable. Yes, it was very stable, usually I have to adjust mine over and over. I think I will buy this strap.*
2.2	Was the vision clear or did it go blurry from time to times?	*Clear the whole time*	*Clear*	*No, it was clear the whole time*	*No, it remained clear*	*It was surprisingly clear too, as I said, I always have to adjust*

						mine at home.
2.3	Did you feel any sort of sickness like dizziness, headache or nausea during the simulation? (if yes):	*True*	*True*	*False*	*True*	*True*
2.3.1	When did the symptoms occur? Was it during a specific movement in the simulation or after you have removed the headset?	*Movement*	*10 minutes in playtest*		*slight disorientation*	*I had discomfort while in the game and it still remains. I have a slight nausea.*
	(if specific movement)					
2.3.2	What were you doing exactly?	*When walking forward and turning with the joystick - better if I move with my body.*	*When going down the staircase*		*Wandering around too quickly on the stairs.*	*I have got the discomfort when walking on the stairs in the lobby while I was in the Avatar Mode*
3. Assessing gameplay: understandability & usability						
3.1	On a scale of 1 to 5 where 5 is the best, how would you rate the learnability of the controls?	*4, why do have to grab with thumbs and not with the trigger button*	*5*	*5*	*4, trigger button would be better to push for grab as used in shooting games*	*4, I always pressed the wrong button when trying to grab, except when I grabbed the ticket because there was that picture telling me to press that button.*
3.2	On a scale of 1 to 5, how would you rate the understandability of getting access to the auditorium room? How straightforward was it to figure out how to do that?	*5, just like in real life*	*5*	*5, I just did what I would do in real life and it seems like that was the way.*	*4, straight forward. Bit confused behind the door at the transition - The screen goes black.*	*5, Very straightforward indeed, it's based on realism and there are textural descriptions available to read what to do.*
3.3	What is your impression regarding	*Hands mode is better*	*I like to see my knees bending*	*Not much difference*	*The two modes are not much*	*Avatar seemed more real as I*

	the movement when you played in Hands Mode and in Avatar Mode?		*when walking on stairs and seating. But the hands in the hands mode are more done than the avatar's hand.*	*between the two when I'm moving, but at least I can see my legs when walking which I cannot see in Hands mode.*	*different. The avatar went glitched, enlarged due to being seated while switched mode, which scene requires standing position, so the guardian reseted that resulted to be raised higher during loading the scene.*	*had a body, especially my arms and legs. I kept looking at my legs while walking on the stairs.The Hands mode is also good, my hands looked very realistic. The walking and moving was essentially similar, so it's not like I had a difference in feeling my weight or something.*
3.4	Which game mode do you prefer of the two when it comes to the interaction with the physical objects such as doors or seats? And why so?	*I prefer Hands mode, it's more smooth, in avatar mode sometimes the hands clash and I don't know what to do.*	*The avatar mode, because I can push the door with both my hand and body which is realistic*	*TheAvatar Mode, because however in Hands Mode I can see the my hands grab, and the avatar's hand does not change.Avatar mode is more immersive*	*I prefer the avatar mode, it is more immersive.*	*I would pick Avatar Mode because when I walk through the door, I can see how I can fit my body. It was both pleasuresome to use the Hands and Avatar mode for grabbing the chairs though.*
4. Mediation of Flamman cinema experience						
4.1	Did you feel like you were physically in the building?	*Yes*	*Almost perfectly yes, but I can feel the headset and the controllers in my hands.*	*Definitely yes.*	*Never with VR. It feels like several monitors around the head, being everywhere that it is just virtua since feeling the headset.*	*I wouldn't say 100%, I could feel the pressure on my face by the headset which continuously reminded me that I'm wearing a display. But If It wouldn't be so, then maybe*

						yes. Otherwise, it seems that my size according to the room size was correct.
4.2	Which decade do you think you were in, and what elements convinced you about that?	*50's - colored film*	*Guessed right, 40-50. The posters and the movie.*	*The 50's or 60's. The clothes of the staff, the movie posters and the movie - was self-evident.*	*Guessed the 50's right, the posters and the uniforms gave the clue.*	*The 50's definitely, I know that movie well and also the cinema uniforms look vintage, the posters at the entrance too gave me the clues. The cinema on the other hand looks modern like it was built in the 70's or so.*
4.3	These are the remaining photographs of the Flamman cinema. How identical was the interior of the simulation compared to these pictures? Do you think the cinema is reconstructed properly?	*Spot lights were not there. The ratio is a bit different than in the simulator. The room feels bigger in the VR than in the image.*	*Very much identical, yes, well reconstructed.*	*Yes, looks exactly alike. Even the pine trees are there. First I wasn't sure that the lobbys size was correct, but now that I see in the picture I'm convinced that it is this small. The ceiling element is also there in the auditorium. Very well re-made.*	*The staircase is steeper, and absolutely recognizes the rooms. Faithful representation of the photos*	*I see no difference, I believe it's reconstructed very well.*
4.4	How would you evaluate the appearance of the simulator? Does it rather look realistic or digital? Why is that so?	*Fairly realistic. People look more fake, very robotic.*	*Some parts are realistic, some are more digital. The texture quality is different in the*	*I would say that I cannot decide. Some things look fake, some are realistic. The shadows on the*	*Rather simulation looking, especially the NPCs. But, realistic expectations of*	*More realistic than other games I tried, only the chair textures looked a bit low quality.*

			auditorium. Those chairs look very low quality.	*walls are a bit dull, the people do not have detailed skins, but their cloth's texture is realistic. The tip-up chairs look very fake and the room gets too dark when the movie is played.*	*what to do for actions, so the feeling is realistic, textures, lights are uneven in scenes, especially in the auditorium. Empty cinema feeling, there are no other people.*	
4.5	Would you rather explore the cinema building on a computer if the graphics were significantly better than on the Oculus?	*No, no that wouldn't be immersive.*	*No, It's cooler to be inside than in front of a monitor.*	*No. Because I like it that I can walk around in it and use my arm movement to open the doors and especially to grab the chairs.*	*No, still prefer in VR*	*No I don't think so. I don't want to open the doors with a mouse, then you would have to disable all those movements as it would be just difficult for the mouse. Also, the graphics were not that bad, and I rather wear VR and use my hands than just not being able to grab the objects with hand tracking.*
5. Impression and Suggestion						
5.1	What is your overall impression regarding this simulator?	*It's promising, but the details of textures, lightings, should look more realistic, including the NPCs.*	*It's cool that I could visit the cinema virtually, I'm not curious to visit the building in real life.*	*Impressive. I thought it would be a cinema app where I will just spawn at my seat and use the raycast to interact with the video player in front*	*I would have enjoyed watching an actual movie with people improve the quality with all the rooms and seats,*	*I actually know the building from the outside because I used to live around there. I think it's great that I got a chance to discover it from the inside*

				of me. I love how much freedom I have by letting me walk around. It's very realistic that I have to get my ticket first and give it to the staff.		*and to get to know what it was before. It was like time travel as well, hoverwer I hadn't lived yet at that time, I could feel this vintageness.Very well done!*
5.2	Do you have any suggestions for this simulator?	*Start movie automatically*	*Fix the texture quality for the seats, and maybe have a selection choice regarding what movie I want to watch when buying a ticket.*	*I saw the ticket specified my seat number but I could not find those on the chairs. I think it would be a good idea if the corresponding chair highlights when I enter the auditorium, or have the seat number on those so I can go to find it even.*	*Multiplayer*	*I only missed other visitors and I felt strange that I was alone in the auditorium. Also, it would be great to make the hands follow the surface, so if I want to, I could shimmy the walls, slide my hand on the fence and follow the curves of the chairs when I touch for example.*