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Abstract:

This project aims to establish to what extent can players navigate in a non-linear (open world) game based entirely on auditory perception and sonification.

Relevant literature in the field of audio games and games, in general, has been reviewed and analyzed to lay a foundation for the design.

Here ideas such as an echolocation tool for the player to ping the environment, voice-assisted guides to help with the mechanics as well as progressing the narrative was presented. Furthermore, locations where players could freely navigate around in and solve fun-yet-challenging navigational puzzles, were also presented.

All of these ideas were implemented using Unity with some additional Audio APIs and a smaller player test that helped in making the game perform more robustly.

Once the final iteration was finished, the results from the player test were gathered and analyzed. Patterns in the feedback started to emerge that while the game experience felt fresh and had some commendable ideas, a lot of enhancements were needed for further iterations in order to make the player experience less frustrating and confusing.

AALBORG UNIVERSITET

A Path to the Unknown

An open world audio game experience

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Contents

1

Introduction

Video games are undergoing a constant growth, with different applications that range from a recreational, to a educational and rehabilitation use. They have reached a diverse audience in terms of age, interests, and needs, but they are still limited to its audiovisual platform that relies entirely on visual feedback (graphics). In the last two decades, the development of audio games (games that rely more or entirely on audio elements) has been slowly an increasing interest for the game design community. These games allow an innovative approach to gaming, allowing for the creation of games that do not have to rely on visual feedback, challenging the player to approach the game through hearing, which is usually an overlooked approach by popular video games. Furthermore, the concept of audio games sheds a light on the importance of the role of audio in video games and media in general, and its implications and considerations in regards to storytelling, sound design, and multimodal processing.

With this project, we propose a number of implementation features for audio games with a focus on a navigation system based on spatial sound source location, grid coordinates, and an interactive “echolocation” system. The main salient concepts as classified by [1] that were approached by this project were those of "crafting the audio game experience" and "input and output techniques". Based on literature about audio games directed to each one of the mentioned target groups, all the considerations made in the development of the "A Path to the Unknown" game aim at addressing and engaging both non impaired and visually impaired people.

Thus our problem statement becomes,

"Can players enjoy and navigate in a non-linear audio-only game, where the challenge for the players lies in designing different audio-only navigational puzzles?"

and to answer that problem statement, this report will present a literature review that based a foundation for how we ended up designing an audio-only game that will evaluate this problem statement. After a grander player test was assessed, the results were discussed in order to propose future work and a final conclusion for how this problem statement can be further iterated.

2

Literature Review

Within the last two decades, developments on game programming, virtual reality systems, and spatial audio have laid the foundation for new virtual experiences. Aided by these developments, the specialized genre of audio based games has achieved the potential of a high level of interactivity and immersiveness in terms of game dynamics, story telling, and sound design, and offering an enhanced spatial freedom. There are several audio games that have been released, encompassing diverse game dynamics and genres, but an in-depth design process and implementation requirements (grounded theory methods as mentioned in [1]) is yet to be fully developed in order for audio games to be able to compete with popular, "best seller" video games.

On an inclusive perspective, there is an immense potential regarding audio games, with an estimated 285 million visually impaired people, of whom 39 million are blind [2]. The development of audio games for visually impaired people is an ongoing field of research, with a branch stating they should be the main target group for this genre. We found that many of the related works do not fully exploit the features that the new technologies allow and lack the complexity and attractiveness that could engage people without visual impairments. That being said, audio games should focus to be universally accessible and attractive, having as a core concept an audio experience that can be approached by anyone.

The following section briefly reviews the literature related to audio games and the developed game at issue. One of the main references to approach this was the paper [1], which concisely lays down the research and experimental developments on audio games since their first conception. In it, the body of literature is divided into 4 distinct themes: Crafting the Audio Game Experience, User Participation and Evaluation, Technological Progress and Audio Games, and Input and Output Techniques. Hereunder the categories that were relevant to this project are developed by referencing the consulted literature, and stating how it related to the development of "A Path to the Unknown".

2.1 Crafting the Audio Game Experience

This category refers to the body of literature that addresses the design and implementation techniques that can and should be considered for the development of audio games. As mentioned before, a special consideration was made regarding this topic, directing most of the design and implementation towards an audio-centered perspective, which as mentioned in [1] is a very rare approach by the available literature. The papers [3], [4], [5], [6], [7], were cited in regards to design techniques and considerations for audio games. Commercial, audiovisual games were also used as reference for both the game's dynamics, concept, and sound design.

2.2 User Participation and Evaluation

As stated in the introduction, the development of "A Path to the Unknown" had as a main goal to approachable, interesting, and engaging for both non impaired and visually impaired users. Limited by availability, the game was tested with only non visually impaired users, failing to properly address both targeted audiences. Two testing iterations were carried out, each one will be developed further in the remaining of this paper. The papers [8], [9] [10], and [11] were considered for the evaluation process.

2.3 Input and Output Techniques

As will be developed later, the initial idea for the game's platform and controls was based on the Oculus Rift VR device and a haptic feedback system, based on the works [12], [13], [14], [15].

To compensate the impossibility to implement these input and output tools, our personal experience with video games as well as the first iteration of the game's testing was taking into consideration to make the suitable design and implementation decisions with the available tools.

2.4 Spatial Audio & Modern Games

This section will review and analyse the literature published by Broderick et al.[16]

Spatial Audio is the representation of sound in a 3D environment which is applied quite often by both Video Games and Virtual Reality experiences.

Audio cues help the navigational capabilities of users within virtual environments [17]. Grohn, Lokki and Takala measured the navigational success with visual, audio and audio-visual cues to find out that the audio only cues performed the worst. But audio and visual cues mixed together (audio-visual) cues gave the strongest results. However, for this project audio only navigation will be tested through a more puzzle based environments by applying game design.

Spatial Audio is also beneficial to sonification by helping the users through pattern recognition and monitoring. For example, sonification has evident examples of being able to aid with other fields as well where complex decision making is needed.

This use of sonification and spatial audio are especially highlighted in games in order give the players cues that for example, "footsteps behind you" could indicate an ambush is incoming and the player needs to react immediately. Additionally, it can also aid the abundance of information by triggering a cue that the player is low on resources or an action cannot be performed.

2.4.1 Head-Related Transfer Function (HRTF) in Modern Games

The human ears are capable of picking up sound sources from three dimensions: Range, azimuth and elevation. How this rather complex and personalized system works is that the brain perceives the sound source by comparing them by difference in time and frequencies as well as how adjustments to that sound are influenced by body proportions such as shoulders, head and ear.

A Head-Related Transfer Function (HRTF) is a measurement of this data that can be applied to digital audio in order to achieve binaural audio. However, the measurements as one might have guessed are very independent from person to person.

The creation of HRTF measurements are also quite complex and not that simple to attain in people's home. For that reason, many games rely on general (average) HRTFs.

This could mean that for some specific users, they feel that the audio quality drops once they enable HRTF features for their video game experience. It all depends on which general HRTF databases that the developers are using. However, with a more focus on developing better audio systems for the next generation of interactive home entertainment systems [18] [19], it is possible that this field of research could improve.

2.5 Dramatic Elements in Games

This section is reviewed and analysed from the following literature by Fullerton[9].

If a game establishes good and interesting world building for the player to explore, a good narrative will also derive from it. As seen with world building in books and movies, games are capable of sharing the same formal elements and even establish the rule-set of this world through gameplay or player active choices. In return, this can also build a more natural blend between the challenges the player needs to undergo and the motivation to solve them.

2.5.1 The Dramatic Arc

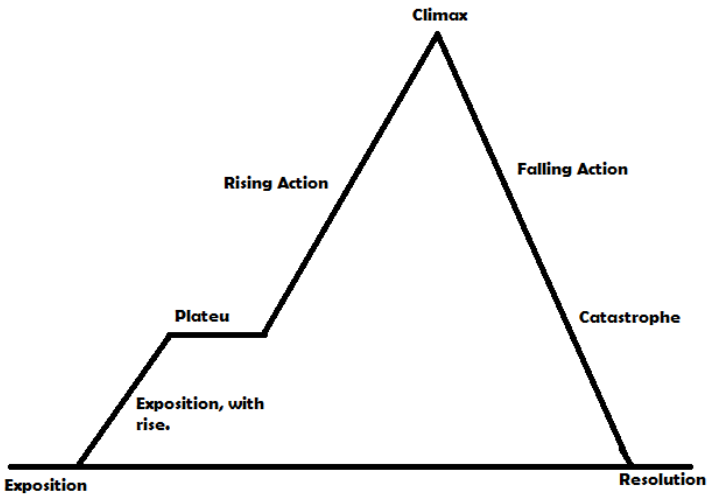

Figure 2.1: A visualization of a dramatic structure showing narrative tension over narrative time.[1]

Most narratives that are experienced can be correlated to the dramatic structure as seen on figure 2.1. These stories tends to introduce a task or challenge in the exposition that the central character(s) of the story must overcome. In order to reach the resolution, the

[1]Source: `https://grantorinohero.files.wordpress.com/2013/12/grandpyramid-of-death.png`

narrative tension will rise (due to the series of actions taken) until finally reaching a climax which releases the tension towards a resolution. A classic example in a character versus character story, the climax is when our protagonist finally defeats the villain.

While games has the same premise in narrative structure, they tend to do things differently.

Games are designed in such that they provide more challenge as they progress. And the formal elements of games allows for the story to develop as the challenge rises. This also leads to the success and failure being entirely on the player's hands. During the narrative tension the player needs to learn how to overcome the challenges and in the climax they need pull together everything they know in order to reach the resolution. A classical climax trope for games is a character versus character arc, where a "Final Boss" needs to be defeated by the player and whom proves to be the most challenging foe so far.

When the player is finally successful at reaching the resolution, there is a strong sense of accomplishment achieved by the player's action that only game experiences are good at stimulating. This combination of conflict in the formal and dramatic systems can provide a powerful experience for the players that makes the game feel very interactive.

3

State of the Art

3.1 Audio games

An audio-game is based only on audible feedback rather than on visual. There is an enormous collection of audio games available on the web; many of which can be found in an extensive list online [20]. Many of them are PC or Mac based, fewer are for iOS or Android platforms, and only a small number are meant to be played with VR systems [21] (which rely on a head-mounted device to track the head, for example). Some of these audio games were tested on the different platforms in order to make the following analysis on the state of the art.

3.2 PC/Mac audio games

3.2.1 Terraformers

In Terraformers [3], the player must find out what happened to a spatial mission crew. There is navigation assistance, for example, a "beeping" when you approach walls, that get annoying at some point [6]. Coordinates are available (e.g.: 20 north, 30 west), but sometimes just that is not enough to have a recreation in one's mind of the world. There is a lack of audio cues at some points where the player feels lost.

3.2.2 Shades of Doom

Shades of Doom [22] is, like the original Doom game [23], a first-person shooter with the same basic plot: a research facility has suffered an accident, and the player is expected to fix it. The narrative voice has low credibility. Players can collect items and encounter (and kill) creatures by using the arrow keys to travel the maze made of rooms. This is aided by a beeping sound cue that becomes scratchy and tiring sometimes. The player can get navigational assistance if needed. The positional sound is good, but requires a large degree of experience to make use of, and many beginning players get killed early on.

3.3 Android/iOS audio games

3.3.1 Papa Sangre

Papa Sangre [4] has a really creditable story that attracts all attention. It has really intuitive commands for moving which makes the playthrough easy and fluent. World audio cues are constituted of real periodical sounds (e.g.: clock ticking, bells of a church),

sound repetitions that the player is able to tolerate more or to find them pleasant rather that beepings or robotic voices.

3.3.2 A blind legend

In a Blind Legend [24], you are aided by your daughter to enter a castle and face the dangers inside. The smartphone's touchscreen acts as a joystick. It does have very credible sound cues, a nice plot, and an engaging fighting system. Sometimes the player feels lost as touching the screen does not tell you how fast you are walking and its occasionally confusing. However, the possibility of asking the daughter for help is a strong point that other audio games do not have.

3.3.3 Blindscape

Blindscape [25] is a short experimental storytelling game where the player needs to tap the screen to see if "there is" something there to move on the story. It is not a really engaging audio game, and it does not have any control other than tapping, which gives a sensation of too low interactivity.

3.3.4 Ear Monsters: 3D Audio Game

Ear Monster [26] is more like a mini audio game where you just have to simply kill monsters and defuse bombs. Ear Monsters uses an advanced binaural HRTF 3D sound system and offers a variety of 3D audio spaces to play in (storm, windy day). It adapts the difficulty as the player improves. It was not played to test its playability as it is not available to download anymore.

3.3.5 The Nightjar

The Nightjar offers a wide variety of audio cues (kittens meowing), nominated for 2 BAFTA GAME AWARDS 2012 with a great story and narrative. It starts with one of the most intuitive audio games tutorials, focusing on assets that non-blind people are not used to and facilitating in this way the knowledge of the game's controls.

3.3.6 Audio Game: Wizard's Choice

Wizard's Choice [27] its a simple yet addictive audio game which follows the game mode that gamebooks [28] do. In it, the player must use her/his voice to select an action to do after a short story is told. Success or failure will depend on the player's decisions on the narrated situations.

3.3.7 Virtual Showdown

Virtual Showdown [29] is a VR game where people use their hearing to locate and hit a ball against an opponent. 3D audio is used to create realistic virtual environments. Unity3D, Oculus, Microsoft, spatialized 3D audio and audiogeneric HRTF with the Microsoft Audio Spatializer are used for this game.

3.3.8 The Vale

The Vale [30] is a story driven, action-adventure that uses the full potential of 3D audio and haptic controller feedback to deliver visceral gameplay that shatters the barrier between

player and character. This audio game has many accollades and famous video games supporters, such as Unity, however, this game must be purchased to play for further review.

3.4 Audio games with additional devices

There are other audio games that make use of additional devices apart from the controllers that the platforms mentioned before offer. When it comes to VR, in [31] an inertial sensor on the head and six vibrating modules are developed as new tactile-feedback devices where haptic stimuli is also used, improving performance and reducing errors when playing. A haptic cane [15] is also developed to recreate VR with high degree of success. It is clear that haptic and vibration-based feedback is a relevant VR creator to take into account for an audio game design [14]. Consequently, a haptic additional device was thought in an initial state but not finally built for this project (see Appendix for more information). There are some toolboxes developed for visually impaired people (not fully blind) to increase recognition in VR [13], as well as facilitating spatialized audio for Unity [32]. Additional tools like echolocalization with Oculus Rift [33] are really useful for locating objects and makes VR games even more realistic.

4

Design

The development of the game's design followed a comparison between general, and audio games different modes. Based on that, a story for the game was designed. The game timeline was developed to fit the story and the gameplay, as well as three navigational puzzles taking place in three distinct dungeons (Which we opted to call temples in order to make them fit with the game narrative) were devised inside the main one for this purpose.

4.1 Type of game modes: General, Only-Audio and decision

When it comes to successful video games, the most used game modes are open world or sandbox games, like Skyrim, inFamous or Just Cause, which achieve a great degree of immersion [34]. Here, the player can choose whether to follow a story (which is in fact linear) or whether to explore the open world on its own, triggering different story lines which could even bias the main one allowing multiple endings [35]. Other games modes are linear, like Tomb Raider: Underworld [36] or the well known Super Mario Bros[37] in its early stages. Finally, we have another type of video games which combine a linear story, but allows the player to travel to the distinct stages of the game to accomplish secondary tasks but not truly parallel story lines. Video games such as Ratchet & Clank[38] or Super Mario Galaxy[37] follows this scheme. Last but not least is to mention that these game often use third person view as the player can notice more elements of the world, allowing also as an option changing to first or second person view.

In regards to audio games, the game mode that most of them present are of a linear fashion, like Terraformers [39], in which the player must find out what happened to a lost crew in space, or Shades of Doom [40], which tries to replicate the famous shooter game DOOM, both for PC/Mac. We find also audio games in mobile platforms, like PapaSangre (iOS) [41], Blind Legend (iOS/Android) [7] or Blindscape(Android) [42]. All the aforementioned games follow a linear story-line where the player normally has to level up continuously until reaching the end. When playing this game mode, the player feels that the play-through is really linear, where it is not possible to choose one or other way to go. This leads a game to not be really immersive and leaving a sensation of limited freedom while playing. It is also worth saying that making an open world audio game is a complex task to carry out as there should be a way that the player can have an "image" or view of the world she/he is facing just by using audio references or cues.

Taking all this into account, A Path into the Unknown implements an open world mode with a non-linear storyline. The player will have to do some tasks in the order he/she elects to achieve the final goal. Therefore, it will have the liberty to move freely around the map to carry out these tasks. The order these are executed will not affect the start neither the end.

All audio games that were studied have a first person approach where the player is highly dependant on the audio cues being heard (specifically through headphones). By considering this, a logic decision was to use a first person mode.

4.2 Narrative

One incredibly important aspect for immersive only-audio games is the story they follow and the way it is introduced to the player. For example, PapaSangre has a really deep, well narrated, full of audio cues, surprising and engaging story, which makes anyone easily integrated within the game. On the opposite side, Terraformers story and its development is narrated by a machine-like voice, being a little uncomfortable or less engaging than using a real flesh-voice with all of its timbre characteristics which enriches the audio spectrum as PapaSangre does.

The Path to the Unknown's story features a world where the main character is blind, establishing a direct association with the lack of visual feedback. Its story is based on a fantasy-magic theme. From section 2.5, it's apparent that world building and dramatic structure can lead to an enjoyable and a need to reach the resolution for the player. For that reason, the summary of the main plot involves a character versus character arc, where the player must overcome three challenges to defeat a monster that is terrorizing the world (2.5.1)

As you can derive from the story excerpt, the player has to collect 3 relics. Each one of them is in a different temple where a navigational puzzle need to be played. The narrative tension will arise for each relic collected. The player can go to whichever temple she/he wants to start with; there is no specific order for doing it. After having collected all 3 relics, they need to be placed on a shrine which is located at the center of the world. This will lead to a magnificent beam of light which will kill the creature causing all the madness and allowing life to come back again to Earth, leading to the game completion and the final resolution of the narrative exposition (see figure 2.1).

For the beginning of the story, the player will have first to find the shrine and afterwards go to the temples in order to get the relics.

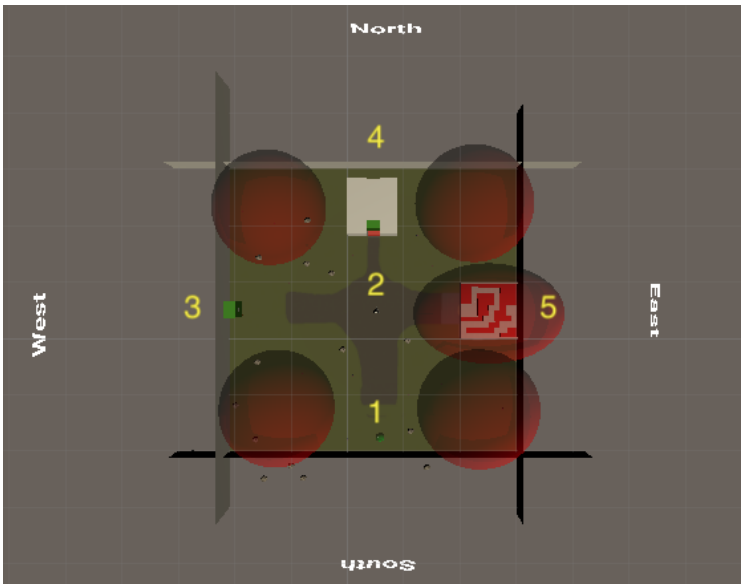

Figure 4.1: Over-world view. 1: Starting point. 2: Shrine. 3,4,5: The three temples.

4.3 Campanilla: The helping fairy

When playing audio games the player depends fully on sound cues making it difficult to fully to construct reality with audio feedback. At some point of the playthrough the player can get lost by missing some information about what was he supposed to do or where has he supposed to go. This situation happens easily in open world games, like in The Legend of Zelda: Ocarina of Time[1], where you have a fairy which you can ask for guidance on which way to go in order to progress your adventure. Other games such as inFamous or Skyrim have a record of the secondary and main missions to which the player can access from the game menu. In this case, we have selected not to have solely a helping menu with a list of tasks to do as that is completely graphical, but a fairy that is at all moments with you, giving important feedback and to which you can ask any time what are the errands pursued. This Fairy is called "Campanilla".

Campanilla adapts its dialogue to the stage you are in, even having different helping intensity levels in some cases if the player does not feel comfortable with the first answer and demands more help, making it more interactive.

4.4 Temples game design

As our story is non linear while having a fixed starting and ending points, the story line must be "eligible". For this approach, we have designed 3 different navigational puzzles inside the main game that can be played in any order. Each navigational puzzle is inside a temple (this is also a reminiscence that the well-known successful Zelda games saga implements) [43].

In short, the different navigational puzzles are:

[1]More information about the mentioned games: `https://store.steampowered.com/`

4.4.1 The Lava Temple

In the lava temple, the character must gain the relic walking through a tricky path surrounded by lava. The tiles are oriented vertically or horizontally (not diagonally) to make the path easier. To guide the player, there are some sound spheres emitting constant, periodic notes with different pitches. The first sphere that the player encounters has a lower pitch and as player makes it to towards the relic, the spheres starts to increase in pitch.

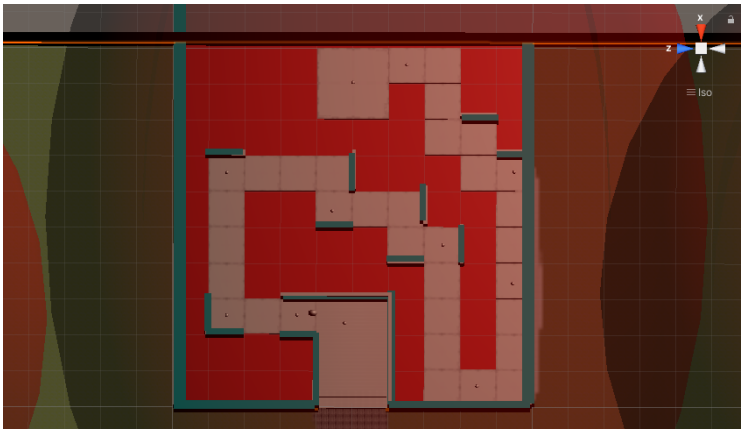

Figure 4.2: Overview of Lava Temple

4.4.2 The Temple of Keys

In this temple, the player must unlock a door by matching the correct "sound key" with the proper "sound sphere". Both are sound objects that emit a constant, looping sound. The sound of the obtained "sound key" must relate to the sound that the "sound sphere" is emitting. When the player brings the correct key to the sphere, a door is opened which allows the player to go to the next room, where she/he will find this same dynamic, only this time he/she is presented with 2 sound sphere instead of just one.

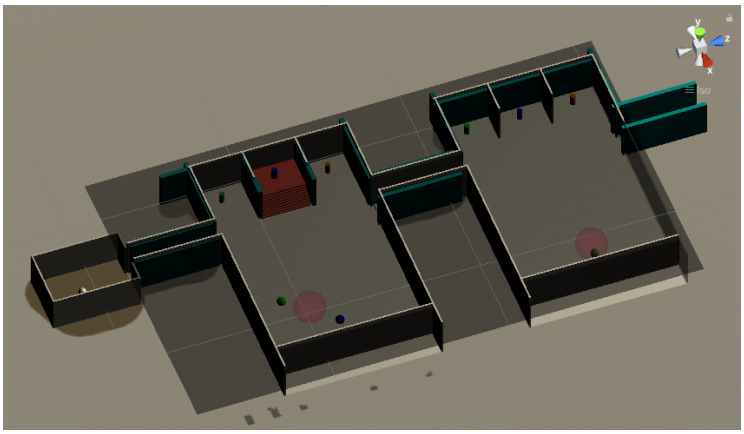

Figure 4.3: Overview of Temple of Keys

4.4.3 The Chess temple

Here the player is in a big space situated on a chess board, like in the first film of the Harry Potter® saga [44]. Here, the player must find a concrete piece on the chess temple.

Once it is found, the player will not be able to move and a sound sequence will be played related to that chess piece (IE: Horse neigh for horse piece). The player must liberate or unlock herself/himself by introducing the correct 6 letter pattern that relates to a sound pattern that is being played (high pitch/low pitch/silence). There are three chess pieces in total in order to unlock and finally get the relic.

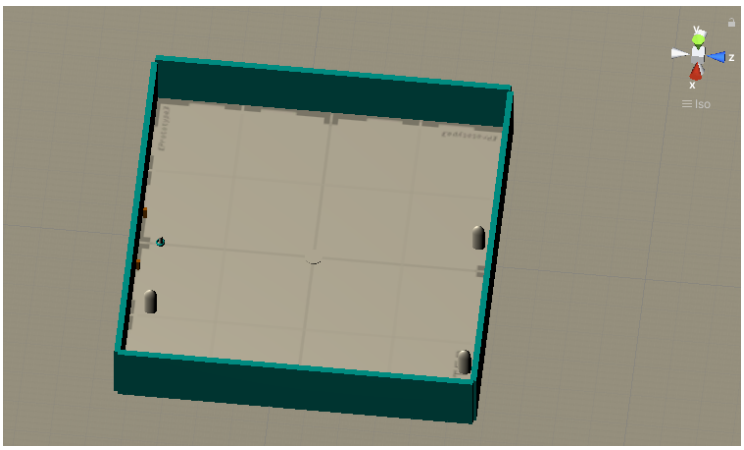

Figure 4.4: Overview of Chess Temple

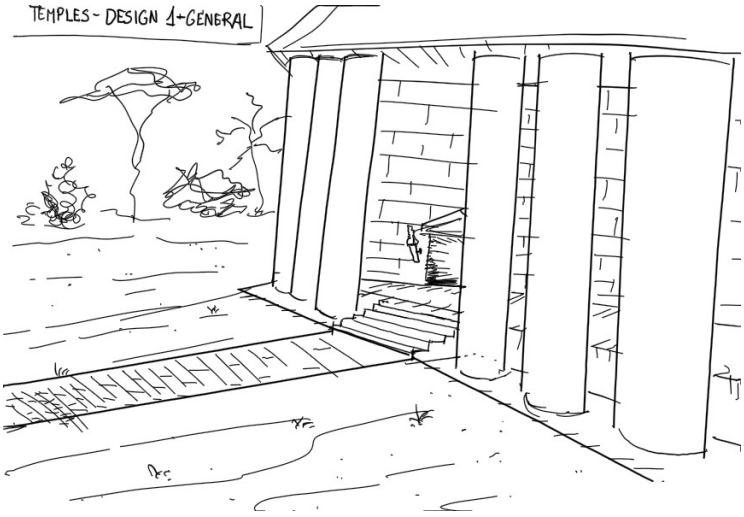

Figure 4.5: Art design for the entrance of the Chess Temple

4.5 Sound Design

An important consideration regarding sound design followed the statement highlighted by [1], that the design procedure for audio games should be done with an audio-centered perspective. In designing and implementing the sound for "A Path to the Unknown", a combination of both an audio-centered perspective as well as a our experience with "open world based games" and video game puzzles were merged so all audio design and implementation could coherently fit into the well defined genre of open world games.

In terms of the sound design requirements, all decisions were made to follow the game's concept of a fantastic/technological world. The quality and characteristics of the sounds

followed the recommendations by [45] , emphasizing musicality and the sound source's characteristics to efficiently convey the information about the environment or the given task.

All of the implemented audio relates to one or more of the three listening modes proposed by [46], and brought to the audio game research field by [45]. This brought the consideration of having the three main puzzles require the player to adopt a reduced listening mode.

Following the classification proposed by [45], this section is divided into the audio elements that were implemented from each one of the categories.

Avatar Sounds

One of the most distinctive sounds in the game is the avatar's footsteps. Like many of the sounds in the game, they serve as a navigational aid, giving feedback to the player of their location in the terrain based on how the footsteps sound depending on the floor's material.

The second avatar sound is the echolocation system. A radar/scanner-like sound was designed to portray the expanding wave that collisions with the objects around the player. Commercial video games that implement a scanner or radar system were reviewed as a reference [47],[48].

The different sound effects when colliding when different objects (trees, walls, lava, etc.) also fall within this category.

These sounds are considered under the casual listening mode, granting the player information about the sound sources around him.

An extra sound effect to mention would be the teleportation sound effect, which allows the player to restart its location in the map, since technically it is an action that the avatar does.

Object Sounds

These were the most recurring sounds implemented in the game. A great part of the navigational aid and interactivity is due to these objects. In this subsection, they are categorized depending on their role in the game.

Continuous, loop-based sounds were designed and implemented to aid navigation. The first one presented to the player is the shrine sound, emitting a slow pulse like sound that serves as an audio cue that informs the player on where the middle point of the map is. This was based on the "foghorn" object implemented in [45]. The musical loop that signals the open door in the temple of keys has this same function.

The adaptive music of the temple of keys and the torches are a variation of these sounds. They consist of a loop sound that aids the player to locate their position in space, but at the same time they allow an extra level of interactivity as the player approaches them.

The second part of the continuous sounds were designed and implemented for interactivity purposes. Examples of these are the sound spheres and the sound keys of the lava temple and temple of keys, respectively. They require the player to adopt a reduced listening mode, where besides their location, the qualities of the sound are the key elements for solving the puzzle (pitch for the lava temple and timbre for the temple of keys).

The brief, "one shot" sounds were also implemented for navigation and interaction purposes. The sound effects of the objects reacting to the echolocation wave (trees, rocks,

spheres in the keys and lava temple) play only once when hit by the wave, requiring the player to carefully listen to their location. In terms of interactivity, the brief animal sounds implemented for the puzzle in the chess temple also require a reduced listening from the player, the proper identification of pitch in the presented sequences is the goal of this puzzle.

The sound of the flocking boid inside the temple of keys could also fall under this category. They work as a masking and dynamic noise that hides the sphere that the player needs to find in order to complete the puzzle, making it more challenging. A brief cricket sound was processed that could work with every instantiation of the boid's agents, without making the whole boid too noisy or intrusive.

Character Sounds

The only sound that fits this category is the dialogues by Campanilla, which even though their main purpose is to instruct the player on the actions to be made on a given task, its dialogues also enrich the story of the game and its development, acting as a character that is part of the story line.

Ornamental Sounds

These sounds help decorate and enrich the world presented in the game, enhancing immersiveness and the auditory experience. These are the forest sounds in the main world, the lava in the lava temple, and the music in the chess temple. It is important to mention that although not interactive, they provide a base for other sound objects that aid location and navigation. The waterfall, a beehive and the cave merge with the world thanks to the ambient sounds, aiding the player to locate each one of the corners of the map.

Instructions

The general instructions and game controls are given by Campanilla, allowing the player to replay them by pressing a key. Another important sound under this category is the cardinal direction sounds, which, when triggered by the space bar, the player gets feedback about which cardinal point he is currently facing.The instructions for the temples are given by a narrator, a reverberated low pitch voice that adds a "boss temple" feeling to the navigational puzzles.

This categorization of the implemented sounds could be developed in more detail, making up for the sounds that fall into two or more categories (e.g. adaptive music), or to none (e.g. the flocking boid).

As mentioned before, musicality was an important aspect when designing some of the sounds. The first sphere in the lava temple, the shrine and the temple of keys' music are all looped sounds that can be heard from a distance, so special attention was taken for them not to create dissonances in terms of pitch, or having them mask each other in terms of rhythm and pulse.

Positioning and mixing the sounds within the game was of great importance for the game's development. An economic and efficient perspective was adopted, in order to avoid overpopulating the game with sounds, which could confuse the player. Only the essential audios were implemented, later mixed to enhance their spatial location. This also allowed for the important sounds to stand out from the rest, conveying the necessary information to the player.

4.6 Design Modifications after First Testing

A first testing of a prototype of the game was carried out to ensure that the basic controls and dynamics of the game were accessible and well understood by the users, which could then lead to a proper, final testing of the main features at issue (the puzzles in the temples, the navigational aid, the echolocation system, etc.) The game's prototype consisted in an "open", main level, similar to the one presented in the final version. The testing was based of from the final version of the Temple of Keys: the player was required to find three sounding objects (with very characteristic sounds, e.g. a chicken's peep) that were hidden in different parts of the level. The player's navigation through the level was aided by almost the same features that the final version presents, mainly: the player's footsteps, the echolocation system and its sound objects triggers, and the cardinal direction positioning. Several general observations were made by the participants, all which were considered and allowed a further improvement of the game. The observations made by the testers and the following changes and considerations that were carried out are listed below:

- Size of the level: Many of the tested players complained about the big size of the level, stating that there were moments were they kept walking for some time without running into or interacting with any objects or sounds. This was modified by decreasing the level's size a fourfold, and positioning each one of the temples on each side of the map.
- Lack of sound references: Some of the players mentioned that it was difficult to locate themselves within the level since there were no audio cues that could inform them if they had previously visited that section of the map. This was modified by adding constant, distinctive sounds to each corner of the map, as well as adding a sound source to the shrine object positioned in the center, and adding a slight variation to the object triggers (trees and rocks).
- Spatial Location of footsteps: One user specified that having the footsteps sound in the center of the spatial audio image was confusing and did not match the rest of the sound's locations. This was modified by changing the sound object of the footsteps from a 2D sound source to a 3D one, and then positioning the object below the player's perspective, as well as moderately filtering the footstep's sounds.
- Bug with sound of object collision: Two users got stuck by continuously running into a wall since the triggered sound that was meant to notify the player that they were facing a wall was only played once, and if the player kept colliding into it, the notification would not be repeated. This was modified by implementing a logic where the notification was repeated intermittently, as well as adding a second, looping alarm-like sound that notified the player they were still colliding with an obstacle.
- Y axis disabilitation: A significant modification that was made and that did not specifically relate to observations by the testers was the restriction of the player's perspective to the x axis. It was hypothesized that a great part of the navigation's and control's complexity was due to the control's flexibility that allowed the player to face any direction in space, considerably sidetracking its navigation if he was facing upwards/downwards without him knowing. This was modified by restricting the camera movement and only allowing the player to pan (move horizontally) its perspective.

4.7 Discarded ideas

In the beginning of this project, distinct ideas were developed regarding the possible usage of Oculus Quest VR and even a additional haptic feedback device was initiated as an extra addition to the Oculus controllers. However, the COVID-19 situation caused the impossibility of developing this for the project. Consider referring to the Appendix (Chapter 10) for more information about this topic.

5

Implementation

5.1 Unity

Unity [49] is a game engine, which tools, features, and cross platform flexibility allows a creative and fluent workflow. It allows the development of all type of virtual experiences (2D, 3D, VR, etc). Supported by the C# programming language, Unity is based on object oriented programming, having as a core element the game objects, and components that modify them. These game objects utilize the engine's graphical tools (e.g. shadow mapping, reflection mapping, bump mapping, etc.) and physics, to render realistic and/or complex virtual environments. At the same time, they can be purely logical objects (paired with the behavioral components) with no graphical counterpart. This latter characteristic was fully exploited in the development of the Path to the Unknown, where no graphical development was required and where most of the procedural, rendering, and processing tasks were given to native and external audio APIs and plugins.

5.2 Audio APIs

For the focused aspect on audio, the limitations of the built in audio system of Unity started to show. We opted in to realize our implementation by adding the following Audio APIs to our project.

5.2.1 FMOD

FMOD [50] is a sound effect engine and middleware that provides audio tools and plugins which enhance the audio functionalities in several game engines such as Unity. Its sound system is provided as an API and its intuitive display and GUI resembles that of a DAW (digital audio workstation). The main features that the engine provides are the built-in plugins and tools that allow a straight forward and flexible processing, automating, and mixing of audio, without the need to delve into the code. Its integration with Unity allows an easy, quick access and addition of recurring components and behaviours (e.g setting a sound source to an object). Its role in the development of this project was mainly to automate and randomize some of the audio features implemented.

5.2.2 Steam Audio

Steam Audio is an API made publicly available by Valve Software[1]. It hosts a wide variety of features also applied to Valve's own state-of-the-art video games. For example in the very competitive game, Counter Strike: Global Offensive [51], the use of a general HRTF

[1]Steam Audio: `https://valvesoftware.github.io/steam-audio/#learn-more`

is an important feature for high level competitive play [16]. It also uses effects such as audio occlusion, where materials and objects in proximity to the sound source can affect its properties. It also supports loading in custom HRTF measurements which should provide great scalability for Audio only games. Both this scalability and the popularity for the APIs applications made us use it to handle the spatial sound objects for our game. Furthermore, Valve has made the API easily accessible for game engines such as Unreal Engine and Unity. On the other hand, the source code isn't publicly available so it's impossible to research how exactly Steam Audio makes use of these features.

5.3 Code Implementation

The Unity game engine allows its users to create *scripts* which is custom classes deriving from the engine's MonoBehavior[2] base class. For the smaller scale of Path to the Unknown, it also made sense to further adapt the singleton design pattern. This made it possible write code for custom behavior and logic for the game in order to quickly prototype them. This section will not include all, but some of the more important scripts that makes Path to the Unknown unique to play within the audio based design structure.

5.3.1 CollisionHandler.cs

```
1  public class CollisionHandler : MonoBehaviour
2  {
3      [SerializeField] Animator echoTrigger;
4      bool _oneFrameEcho;
5
6  { ... }
7
8      private void LaunchEcho()
9      {
10         if (Input.GetButton("Fire1") && _oneFrameEcho)
11         {
12
13             echoTrigger.SetTrigger("EchoPlay");
14             gameObject.GetComponent<AudioSource>().Play(); //Echolocation SFX
15             StartCoroutine(FreezeInput());
16
17         }
18     }
19 }
```

Listing 5.1: CollisionHandler class for handling the player input of launching the Echolocation effect.

The function LaunchEcho() is responsible for checking the player's input on the left mouse click. Once pressed, the animation component attached to the player sends out a torus shaped ring, where the collision checks the objects it collides with. If the object collided with has a collider trigger and a sound file attached, it will play that audio which is spatialized through the Steam Audio API. Once triggered, the oneFrameEcho boolean is set to false, so all of these events being fired are only happening on one frame, instead of

[2]Unity MonoBehavior: `https://docs.unity3d.com/ScriptReference/MonoBehaviour.html`

on all of the frames within the Update() function. Not having it triggered on one frame could cause unwanted issues such as the audio play event being triggered multiple times.

5.3.2 NavigationHandler.cs

```
1  public class NavigationHandler : MonoBehaviour
2  {
3  [SerializeField] AudioClip sfxWall;
4  [SerializeField] AudioClip sfxTree;
5
6  { ... }
7
8  void ReadCloseCollision(Transform originObject, float distance)
9      {
10         Vector3 fwd = originObject.TransformDirection(Vector3.forward);
11         RaycastHit hit;
12         if (Physics.SphereCast(originObject.position, playerCharCtrl.radius, fwd,
               out hit, Mathf.Infinity))
13             if (hit.distance < distance)
14             {
15                 string objectToRead = hit.collider.tag.ToString();
16                 if (playOnce) {
17                     switch (objectToRead)
18                     {
19                         case "Wall":
20                             playerListener.PlayOneShot(sfxWall, 1);
21                             scd_playerListener.PlayOneShot(hitWallCue, 0.7f);
22                             warningSystem.Play();
23                             playOnce = false;
24                             break;
25                         case "Tree":
26                             playerListener.PlayOneShot(sfxTree, 1);
27                             scd_playerListener.PlayOneShot(hitWallCue, 0.7f);
28                             warningSystem.Play();
29                             playOnce = false;
30                             break;
31                       { ... }
32                     }
33                 }
34             }
35             else
36             {
37                 playOnce = true;
38                 warningSystem.Stop();
39             }
40     }
```

Listing 5.2: NavigationHandler class for handling audio being played when the player walks into objects

In this class, all logic linked to navigation is handled. Such as the player being able to use an auditory compass as well as a multitude of sounds triggering once the player collides with an object. From the code excerpt above, the ReadCloseCollision function makes sure to play an auditory cue when the player walks into a 3D object in the game world. This

is especially important, in order for the player to get an idea of the area they are standing in. With no cues, they could end up walking endlessly into a tree without progressing anywhere.

From lines 10 - 12, a vector pointing forward from the player camera is defined, as well as a RaycastHit variable. These definitions are used in the if statement that a collision sphere is cast in front of the player, with the same radius as the Character Controller component. Once this condition is met, the distance is calculated from the distance of the object collided with, with a user set distance. Afterwards, it allocates the string variable, objectToRead, to the tag of the object collided with.

Lastly, the switch case reads this information and plays the audio depending if the player steps into a wall or a tree, and so on. Inside each case, the appropriate sound file is played as well as the warning system which signals the player to step away.

Once the player steps away, the playOnce boolean is set to true to make sure that everything is only being executed within one frame of the Update() function, as well as stopping the warning system.

5.3.3 EffectZoneController.cs

```
1     public class EffectZoneController : MonoBehaviour
2 {
3     [SerializeField] AudioMixer mixer;
4     [SerializeField] AudioMixerSnapshot[] snapshots;
5     float[] _weights;
6
7 { ... }
8
9     void BlendAudioSnapshots(int triggerCase)
10    {
11        switch (triggerCase)
12        {
13            case 1:
14                _weights[0] = 1.0f;
15                _weights[1] = 0.0f;
16                mixer.TransitionToSnapshots(snapshots, weights, 0.5f);
17                break;
18            case 2:
19                _weights[0] = .25f;
20                _weights[1] = .75f;
21                mixer.TransitionToSnapshots(snapshots, weights, 0.5f);
22                break;
23            case 3:
24                _weights[0] = 0.0f;
25                _weights[1] = 1.0f;
26                mixer.TransitionToSnapshots(snapshots, weights, 0.5f);
27                break;
28        }
29    }
30 }
```

Listing 5.3: EffectZoneController class for handling multiple audio snapshots being transitioned

In our environment, it would be required for certain areas to have audio reflections of the zone. A Cave or a Temple will have larger reverberations for example. To implement a system for this, we decided to script it through Unity instead of FMOD in order to retain the Steam Audio API spatialization properties. How this class works is that a ray cast is calculating the position of the player's distance to the zone at issue. Once the player gets closer, the triggerCase variable gets increased where the weights are handling the transition from one snapshot to the next, as seen from line 140 - 142 for example. Snapshots are a way to store data on the audio channels, such as how wet/dry certain effects are and so on.

In our case, we are applying this system to apply a low pass filter, once the player gets lost and wanders into the forest, away from the Temples. As the player gets close to these out-bounds, the low pass filter starts to incrementally filter the ambient sounds being played.

5.3.4 PlayFootsteps.cs

```
1  ublic class PlayFootsteps : MonoBehaviour
2  {
3      [FMODUnity.EventRef]
4      public string inputsoundFootstepsMarble;
5      public string inputsoundFootstepsGrass;
6      { ... }
7
8      void Start()
9      {
10         InvokeRepeating("CallFootsteps", 0, walkingSpeed);
11     }
12
13   void CallFootsteps()
14     {
15         if (playerismoving == true && textureGrass > 0)
16         {
17             FMODUnity.RuntimeManager.PlayOneShot(inputsoundFootstepsGrass);
18         }else if (playerismoving == true && textureConcrete > 0)
19         {
20             FMODUnity.RuntimeManager.PlayOneShot(inputsoundFootstepsStone);
21         }
22         { ... }
23         }
24     }
25 }
```

Listing 5.4: PlayFootsteps class for handling footsteps sounds in combination with fmod, for playing snapshots being transitioned

In order to listen to the player footsteps, the texture of the terrain he/she is currently on is checked. This is done by another script, CheckTerrainTexture.cs. Based on the terrain type (e.g.: Marble, Grass...), an FMOD event is triggered with a random play function, so as not to play the same sound when walking on a given terrain, sounding more realistic.

Figure 5.1: FMOD block to randomly select one sample from a sample set

5.4 Adaptive Music

The adaptive music for the temple of keys was implemented through FMOD. It consists of a 4 measure loop that repeats continuously, starting off with a violin instrument and as the player approaches the temple, each one of the 4 instruments fades in to play the track with the complete instrumentation once the player reaches the temple. To achieve this, the instruments were exported as separate audio files and imported into an FMOD event. There, a distance parameter was set to each one of the tracks, and setting a range of minimum and maximum distance (here, the distance refers to how far the player is from the audio source), each track's volume was automated, set to fade in at a specified value of the distance parameter.

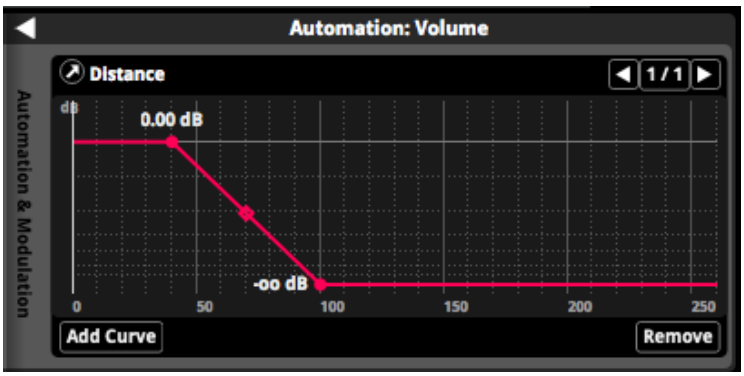

Figure 5.2: FMOD block to automate the instrument's/music track's volume as a function of the player's distance

In Unity the FMOD Studio event emitter component was added to a 3D object and set to trigger the music event, which automatically calculates the distance between the object that has the FMOD listener component attached (main player in this case) and the object which has the described component attached.

5.5 Flocking Boid

The goal of the flocking boid (a flock of "flying objects" simulating the behaviour of birds) implementation was to include a dynamic sound object that could exploit the spatial audio environment, adding an ornamental game object that could enhance immmersiveness in the 3d space.

It follows the behavioural principles of alignment, steering and avoidance proposed by [52] where the interaction of the independent agents in the flock with its surrounding agents and obstacles translates into the general flock's behaviour. The implementation recommended by [53] was opted due to its sphere-shaped ray cast that allows a smooth and organic behaviour from the flock's agents.

The effect of the flock surrounding the sphere object was created By enclosing the sphere with blocks that could be seen as obstacles only by the boid's agents, allowing the agents to fly around the object while maintaining a distance from it in order to avoid a complete masking of the sphere's sound.

As a side note, while researching for references and related works, it became apparent that the implementation of flocking boids as interactive sound objects is still and overlooked design technique, perhaps as a consequence of its computational complexity that requires each agent in the boid to be a sound source, as well as the sound design limitation to short sounds that get duplicated for each one of the boid's instantiations.

5.6 Implementation of the Temples

5.6.1 The Lava Temple

In this challenge, once the player approaches the temple he will eventually walk into a trigger which warps the player to a fixed position. Here the player is introduced to the challenge and is then given instructions by the temple's narrator. Once the audio is done playing, the next set of logic executes. Here 8 sound objects are spawned with limited sound roll off, so the player can only hear one note at a time. The notes are played from a low octave C and up in the key of C Major. The trick is, that the player has to follow the direction of these notes carefully, in order to not fall off the platform they're currently traversing. If they fall, the player is warped back to the fixed position at the entrance of the temple where they will have to start over. Once the player managed to follow the direction of each sound object, they are awarded with the temple's relic and are teleported back to the Shrine.

5.6.2 The Chess temple

For the chess temple, the player must find out 3 chess pieces and unblock them with a code which will depend on a concrete sound. Chess pieces do not emit any particular sound until discovered, so the player, aided by a quadrant navigation (e.g.: A2, F8) voice system, should evoke a recreation of the space and where she/he is located on. The quadrant coordinates are calculated on PlayerTemplePosition.cs script. Using its relative position, the player must find the horse piece first. The exact location of the piece is told in the temple's introduction, so the first task is simple. When encountered, the horse will emit a sound sequence comprising of silences, and high and low pitches. A 6 letter key sequence (H for high pitch, L for low and S for silence) must be introduced to liberate the chess

piece. The help screen is updated with these new keys and their meaning. When any of these keys are pressed, a special sound is played, so the player gets audio feedback. Also, a failure sound is played when failing and a wind sound is played when "it is not the time" to press keys. Audio feedback when interacting is important where visuals are not available. The same procedure is iterated 2 times, with available help if the player is confused. This help sometimes turns into a solution if the player is lost.

5.6.3 The Temple of Keys

In this last challenge, players are introduced to the instructions of the challenge by the temple narrator. The player is navigating a room that has three distinct keys on display. Each key has a certain sound source. Each time the player walks into one of the keys, sonification is utilized by having a "success" sound play and a static boolean is set to true. They need to collide with a certain sphere in each room which are surrounded by a flock of boids. If the player enters the sphere without the correct static boolean, or with no keys at all, a "fail" sound is played in order to indicate that they need to try again. All the static booleans are reset in this failed state. Once the player manages to successfully unlock the sphere with the correct key, a sound of a door opening plays at the position of the hallway leading further into the temple. A melody is also played in this hallway in order to guide the player towards the correct path. For the next room, the challenge is repeated again, but this time two spheres need to be unlocked with two out of three keys. Once the player succeeds at completing this area, they are rewarded with this temple's relic and they get teleported back to the shrine.

6

Evaluation

This chapter presents the results from the player test by presenting the participants with the final iteration of our game.

6.1 Methodology

In order to gain an insight on how the navigational puzzles within a Visual Impaired designed game was received by users playing the game, we opted for a feedback gathering purely based on quantitative data by using Google Questionnaire Form [54]. This decision was made due to the current world situation while developing this report. Our initial approach was to have our research question answered by applying convergent parallel mixed methods [8], since this convergent approach is also recommended for play testing of video games, by having users think out loud, answer observational questions as well as logging quantitative data in parallel [9].

The questionnaire was designed in three parts. The first part explores background details such as Age, Gender, whether they are Visually Impaired or not, and how often they play video games. The second part of the questionnaire asks about the overall experience with the game as well as how the different auditory systems within the game functioned. The questions addressing the systems were rated by the users, using a likert scale format [10] with some essential questions requiring the user to state why they chose that rating.

The third part was inspired by the Microsoft Desirability Toolkit [55] that, applied to our design, requires each user to pick 5 card out of 21 total cards. The questionnaire then requires the user to write the reasoning behind picking those cards. This was done in order to evaluate different parts of the game (The overworld and the three temples), by comparing the card picking and feedback side by side. It also avoided having the questionnaire be too bloated, and have the users tirelessly clicking through it.

6.2 Results

6.2.1 Background Information

The sample size ended up being 10 participants. 80% were male and the rest were female. The average age of the respondents was 30 years old, approximately, with the youngest participant being 21 years old and the oldest participant being 47. The age group is well distributed. However, none of the users we got to reach out to were visually impaired, so it's not possible to make any comparisons between core user and average user. Three of the participants responded they play video games frequently (#1, #8 & #9), with one of the participants answering he is playing video games all the time (#5). #3 and #7

responded that they never played video games before. #4 and #10 rarely plays video games, with the rest of the participants playing video games occasionally. The sample size also provides a good mix of both hardcore and casual users of the medium. Only two participants answered that they had played audio games before (#2 & #8).

6.2.2 Overall experience with the game

The mean and standard deviation for the following scales gave:

Scale	Mean	Std. Deviation
1. *I found the game complex to play*:	**3.9**	**0.9944**
2. *I thought the game was easy to play*:	**2.8**	**1.2292**
3. *I think I would need additional help to play the game*:	**4.1**	**1.1005**
4. *I found the various functions in the game were well integrated*:	**3.6**	**0.8432**
5. *I thought there was too much inconsistency with this game*:	**3**	**1.1547**
6. *I imagine that most people would learn to play this game very quickly*:	**3.4**	**1.1737**
7. *I felt very confident playing the game*:	**2.6**	**1.1737**
8. *I needed to learn a lot of things before I could get going with this game*:	**3.5**	**1.4337**

These results show that the average participant was struggling with this game. Some of these scales also required the user to write their reasoning on why. Some examples include:

- *"There was a lot of information at once"* - Participant #6 (As a response to scale #3)
- *"I thought the 3D audio was pretty cool and worked well"* - Participant #1 (As a response to scale #4)
- *"The voice (Campanilla) was a bit too annoying and too much"* - Participant #5 (As a response to scale #5)
- *"Yes, but maybe some shorter / to the point instructions are needed."* - Participant #2 (As a response to scale #6)

6.2.2.1 Feedback on Auditory Systems

Scale	Mean	Std. Deviation
1. *The audio helped me navigate the environments*:	**4.2**	**0.6324**
2. *The audio helped me interact with the environments*:	**3.2**	**1.3984**

The result of the auditory systems show more positive feedback. Some of the responses on why, states that:

- *"I could locate the sounds"* - Participant #9 (As a response to scale #1)
- *"I could tell where a tree was placed and so on"* - Participant #4 (As a response to scale #2)

For the sounds that the participants paid close attention to, the echolocation effect to locate sound sources as well as the narrative speakers (Narrator and Campanilla) were mostly mentioned.

Sounds that were hard to understand for the participants were the Narrator and Campanilla as the sound effects and sound levels are too high.

6.2.3 Navigation in the Overworld

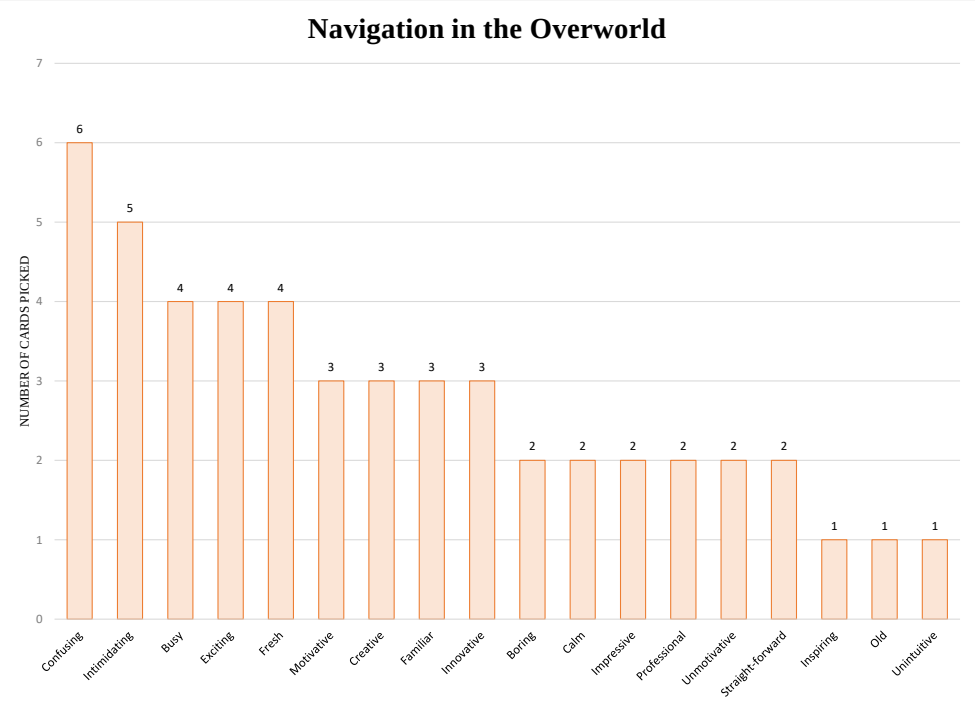

Figure 6.1: Histogram showing which cards all of the participants picked for navigating the overworld. (n = 10)

In the overworld, figure 6.1 shows the distribution of cards that all the entire test sample picked. Confusing and intimidating are the two most picked, following a more even distribution. This shows that the reception of the overworld was both positive and negative. The following examples says,

- *"Too many sounds going off at once in the beginning ..."* - Participant #1
- *"Too many things happening at the same time ..."* - Participant #2
- *"I got easily lost"* - Participant #6

For the positive feedback, the participants expressed the following,

- *"It was exciting and fresh because I haven't tried this before. Innovative with the sound. Busy and confusing because I didn't know what I was doing."* - Participant #4
- *"Creative, innovative because I haven't tried something like this before"* - Participant #5
- *"It was new for me and I had fun with this and liked playing it"* - Participant #7

6.2.4 Navigating the Three Temples

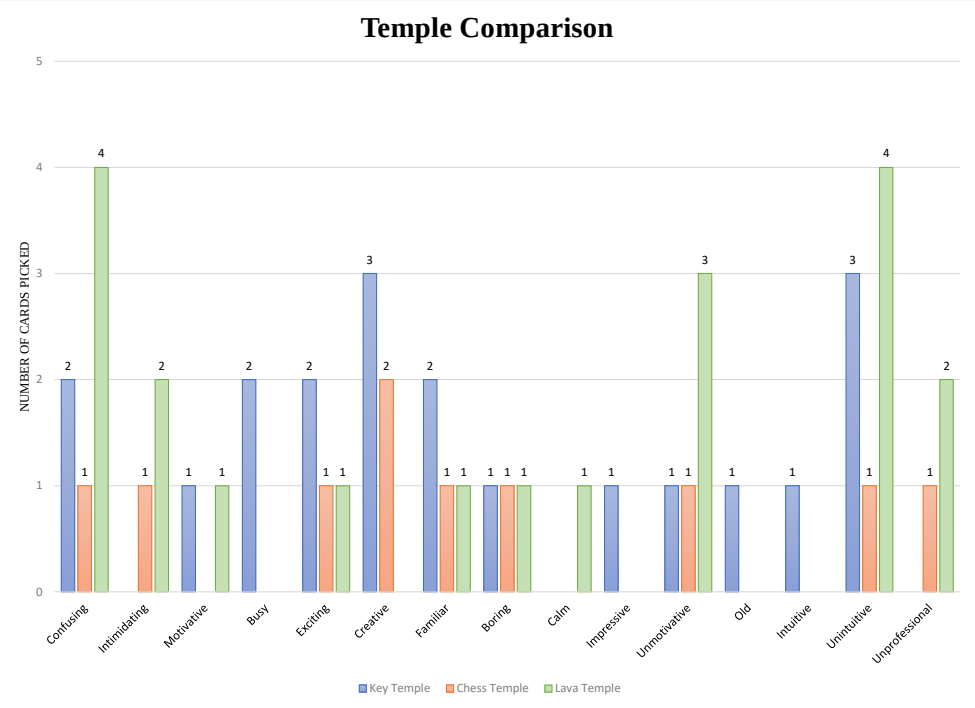

Figure 6.2: Histogram comparing cards picked across all three Temples. (n = 5)

The following figure 6.2 draws a comparison between all three temples. Both the Key Temple and the Lava Temple had 4 participants stumble across it. The Chess Temple was only discovered by 2 participants.

For the Key Temple, most participants agreed that it was creative:

- *"Creative because i got the idea that the sound you had to pick up needed to match with the sound you heard with the echolocation thingie.. I thought that was creative."* - Participant #1
- *"Creative because the audio guided you."* - Participant #5
- *"Cool puzzle for only having to listen to audio"* - Participant #9

However the experience also felt equally unintuitive:

- *"Unintuitive cause i spent a lot of time getting stuck in walls"* - Participant #1
- *"The sound wasnt triggering all the time"* - Participant #9

It's also worth noting that cards such as Confusing, Busy, Exciting and Familiar were picked. Additionally, only one participant didn't manage to complete this challenge which marks it as the temple which most of the participants were able to complete.

The Chess temple was not discovered by many of the participants, so the results aren't very strong. Only Creative was picked by both participants that found it:

- *"Creative because the idea of a chessboard could work out cool"* - Participant #5

Only one participant managed to beat this temple.

At last, for the Lava Temple, all participants agreed that it was both confusing and unintuitive to play. Most also picked the card depicting that they were unmotivated to keep trying.

- *"It was so hard. I kept falling into the lava.. I think this type of challenge is very tricky to implement in audio only games"* - Participant #1
- *"It was super hard and I gave up ..."* - Participant #6
- *"The cards speaks for themselves. I didn't really understand this temple and I couldn't beat it."* - Participant #9

No one managed to complete this temple.

6.2.5 The Final Questions

For last section of questions that wrapped up the questionnaire, users were first asked if they managed to finish the game by completing all of the temples and gathering their relics. No one in the entire sample was able to complete it. Furthermore, users were asked, *"What would you add or change in order to improve this game?"* which gave the following responses:

- *"Add better instructions, a more linear tutorial level before you let players venture into a big world, especially since this is a very new way to play a game. This shouldn't be played with keyboard and mouse at all I feel, I would consider other controls. Better sound design as well, some sounds were really good like the shrine.. others could be replaced like the tree. it sounded like an earth quake was hitting it.. a bit confusing to understand. I also feel that the narrator shouldn't bomb you with information.. just take it easy and slow in bits and pieces."* - Participant #1
- *"Better instructions. Maybe the start is more grounded as you learn how to play this game. Get rid of the fairy voice"* - Participant #7
- *"Also, for the first task (Standing at the Shrine) tell the player to take 10 steps to the north, or something like that. I started walking and walking and I wasn't sure I was going to arrive anywhere"* - Participant #2

For the final question asking if the participants experienced any game-breaking bugs, two respondents answered yes:

- *"The menu didn't work, the dialogues could start before some others aren't finished, some actions were unable to use until I wait long delays and the fact that I miss some instructions once could make people go nuts."* - Participant #8
- *"Sounds wasn't triggering all the time when clicking mouse"* - Participant #9

7

Discussion

In this chapter, we discuss the results received from our participants in chapter 6.

7.1 General Reception of the Game

Looking at the results from section 6.2.2, the standard deviation taken from each likert scale shows that the score from each participant tends to have a higher variation from the mean. This could be due to players struggling at understanding the instructions of the game, especially those not so familiar with video games since this game for example uses a very standard control setup for a first person experience. The more experienced gamers understood what the controls were for, but still this experience of only relying purely on auditory perception was quite challenging for them as well. There was confusion with how the systems worked and with mechanics such as the Echolocation, which lacked a proper explanation within the game. Also quite a few of the participants noted that a better tutorial was needed before throwing players into this open world 6.2.5. From the feedback on the auditory systems 6.2.2.1, the standard deviation taken on the first scale shows a smaller variation from the mean. The users expressed that the general HRTF filter provided from Steam Audio worked quite well as they were able to both locate and approximate the distance on sources. The problem is, however, it was hard to pay attention to the sounds since quite a few expressed that a lot of audio was playing at once with Campanilla's voice triggering in conjunction with firing the Echolocation mechanic.

7.1.1 Feedback on traversing the Overworld

As mentioned from 6.2.3, the feedback was both positive and negative in regards to traversing the overworld. Some of the participants were actually excited on how this was a new experience for them. Especially those who are more on the casual side of gaming. It was also apparent that there was not enough systems in place to make sure that the narrative progress flowed smoothly. Section 4.3 mentioned that Campanilla adapts its dialogue to the given stage of the player, but for most users it seemed her dialogues where too long, while they were trying to focus on gameplay mechanics. A solution to this could be a better approach for the tutorial part of the game and have a system avoiding that sounds overlap too much as this created most of the distress in the players. Also, with the overworld being considerably a large area, only one participant (#6) noted they got lost. However, half of the sample size was not able to locate any of the three temples at all. The question becomes whether if they *felt* lost or not as they explored the open areas.

7.1.2 Feedback on solving the Temple puzzles

6.2.4 mentions that The Temple of Keys received most of the positive feedback. The participants really liked the idea that the timbre of sounds had to fit with each other categorically as explained in 4.4. This interaction with sound was also introduced in the Lava Temple, where the pitch of the sound guided the player where to walk. Although, players felt that this temple was very difficult. It can be blamed on the core of its design. Players having to balance carefully on a path is a challenge relying too much on visual information. A solution to these sort of challenges could be to introduce more limited degrees of freedom. This in return could also beneficial for players to have a pleasant experience with for the other Temples. The Temple of Keys had the complaints about the movement being too free, so while users enjoyed playing it, they felt getting stuck too often. It is hard to conclude much on the Chess Temple due to a low participant number. One user noted that the instructions were too confusing so they had to leave the temple and the other managed to beat it.

7.2 Concerns

When conducting the experiment, it was originally planned to make the test transition very smoothly for the player since we were worried that downloading, and manually installing the game would be too much work for the participants that were not curious enough to try the game out. How this was planned was that the game would be built as a WebGL project [1] that only required the user to play it through their browser, which would also automatically direct them to the questionnaire. This was not possible since we were using custom APIs (Fmod & Steam Audio) for the audio systems our builds would result in failure. The alternative process was then to give the users a lengthy guide on how to both install the game and access the questionnaire afterwards. During the sampling of participants, some noted that this was a lot of work put on them.

It was also overlooked to set a required text length for the open questions, since two users inputted few key strokes in order to pass the required text fields so as to speed through the questionnaire.

Due to these concerns, we felt that this type of test was better suited for the original plans described in section 6.1.

[1] Unity WebGL: `https://docs.unity3d.com/Manual/webgl-building.html`

8

Future Works

This section will describe features being added for the next iteration of the game based on the feedback gathered from the test.

8.1 A better tutorial level

A pattern started to emerge that players got very confused during the first moments in the game. Here we propose to add a more linear section. The users gets to train and warm up their hearing senses in order to understand the echolocation tools better as well learning to judge and place the distances of auditory cues they trigger within this level. The story during this part the story telling will be very minimal in order to avoid the overlapping of sounds phenomenon which put a lot of the players off.

8.2 Professional narrators and shorter dialogues

Some people found the "Campanilla" voice or the "Boss-Temple" voices hard to understand, even annoying, or that they speak too much. Shortened conversations may be developed for further version of the game, as well as the usage of "proper" voice actors, as we, the game developers, were the ones recording the speeches for all dialogues.

8.3 Limited degrees of freedom for the Temples

We propose for future iterations, the open world should in fact still remain nonlinear, but offer better tools for the player to locate the next area they need to go to as well as having an idea when they are walking off track. One of the participants had an interesting suggestions about adding "shadows" to where you've traversed previously:

- *"As sound was the only available sense, I had to rely a lot in my memory to navigate around, it would have been nice to had a visual map or even some "shadows" showing were I have been before to compensate the lack of other spacial senses (aside from vision) in a virtual environment"* - Participant #8

While we still like to explore having an open world environment for our game, we believe that puzzles requiring a lot of movement creates a paradox effect for the temples, where the freedom of the player ends up adding an extra layer of challenge in itself which can become quite frustrating. This means that the design of the Temples needs to adhere to a design choice of being more linear as well as the player on being able to move within a limited pattern.

8.4 Adjusting the Complexities of Control

The players complained about the current Keyboard and Mouse setup used to control the game. Especially for the Lava Temple it proved to be difficult cause the player could easily align themselves with an offset enough to fall off the maze platform and fail the challenge. Further iterations would change the classical control scheme out with the motion controls of for example Virtual Reality and add additional guiding layers on top by having elements such as touch, obstacles and sound be simulated by haptic feedback.

8.5 Personalized HRTF

As brought up in section 2.4.1, the current solution games adapts to, is the use a general HRTF. In our implementation we opted in to use Steam Audio, which also allows for personalized HRTFs to be loaded in for the spatial features of the Unity project (5.2.2). Our participants expressed general satisfaction with the binaural audio, however, due to the test being purely quantitative, we could not observe qualitative how every participant performed. We believe that a personalized HRTF can only benefit the experience and for that reason, we will continue to use Steam Audio or any other Audio API that allows for this feature in order to increase the scalability with future enhancements in this field of research.

9

Conclusion

The audio game "A Path to the Unknown" presents an non-linear approach to state of the art audio games, developed with sonification and navigational interaction rarely seen before for audio games.

The game adds new features to the toolbox of audio games. Such as a tool simulating echolocation in order to scan and ping the environment, an open world environment with a semi-non-linear game story, which further enhances the different approach to audio games. The ability of merging the audio capabilities of different Unity APIs (FMOD, Steam Audio) in combination with HRTF, sound design and its audio only navigational puzzles which fully explores these capabilities, have led some players to qualify "A Path to the Unknown" as a "creative" and "innovative" audio game.

However, a majority of players have found this game "confusing", felt "lost", or did not manage to locate themselves within the world. Besides, half of the participants were not able to locate the temples where the navigational puzzles were held. The majority weren't able beat them either. In regards to this point, and possibly, maybe related to the current covid-19 situation, not enough reviews were received so as to conclude firmly a faithful statement. It wasn't possible to employ additional methods to evaluate the player experience as well.

The game underwent two iterations. Where size such as the scale of the environment was down scaled to the second iteration that became the final test. After a evaluation, our future work contemplates a linear, easier tutorial, as suggested. Also, the idea of implementing "shadows" where player has already traverse the world could be a innovative well-received idea for the audience and will aid the players to locate themselves. Complexity of navigational puzzles in terms of world size could be also reduced. Professional dedicated narrators and a revision of dialogues length could improve the audio game too as well as making sure a bombardment of sounds cannot be heard at once. Finally, a personalized HRTF may be used to increase the grade of the audio plausibility in the game.

It must be said that the initial idea, as well as some player suggested, the fully playability and audio experience of "A Path to the Unknown" will be achieved with its implementation with a head mounted device for an immersive VR-like experience. Our hopes is that audio echolocalization and cues will be easily understood and managed by the player's head-tracking, leading "A Path to the Unknown" to a better stage.

To answer the problem statement; the implemented navigational aids proved to be helpful to the players which translated in their enjoyment of the game, but not without major issues of course. Without the proper implementation of a tutorial and various other systems that clarified the game's tasks and dynamics, patterns started to emerge in the feedback from the players. In order to make the game accessible to a larger player-base, further iterations on this type of game must be worked on in order to test new ideas that could give non-linear audio games a strong and new experience for both casual and avid players of the medium.

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10

Appendix

As previously mentioned, the goals of this project had to be re-adapted due to the current situation caused by corona virus. At the beginning, A Path into the Unknown was intended to make use of Oculus Quest VR, and to have an additional device for haptic feedback. Games where designed taking these possibilities into account so the intended immersiveness was achieved at a higher degree other audio games have not reached. Unfortunately, these ideas were discarded when the situation did not allow us to develop and test on the desired platforms. At the bottom of this section discarded artwork can be found.

10.1 Oculus quest and discarded game designs

With Oculus quest, we could have as an input the direction that the player is looking at in 3D, so we could filter incoming sounds matching the position of the head in space. This integration makes the game and world more realistic and we could make the player to have a sensation of "being" really there. Taking the possibility of knowing where exactly in space the player is looking at, these games were devised (some of the final games are a variation of them):

The Temple of sound keys

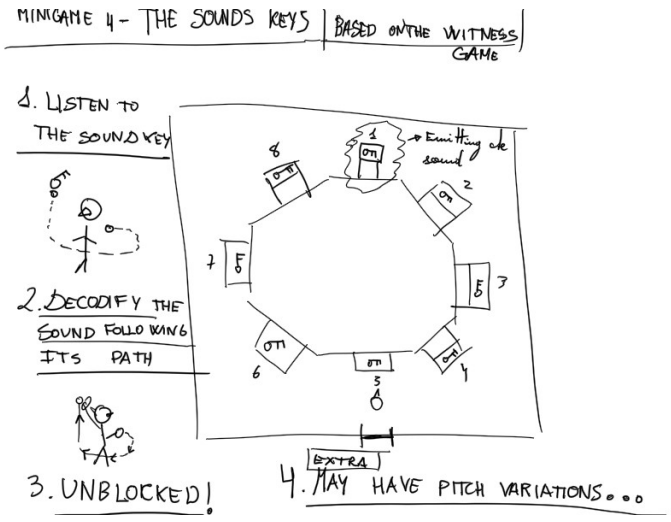

Figure 10.1: The Temple of sound keys sketch

In this game idea, we would make use of the Oculus rift controller so the player "paints" the path a sound flying key travelled around us in all directions (including above us) to

exploit the possibilities of 3D audio and HRTF in Unity. This game idea was designed as a more extended version of a audio puzzle found in The Witness [56].

Figure 10.2: Oculus Rift controllers

The crazy/mad flying band

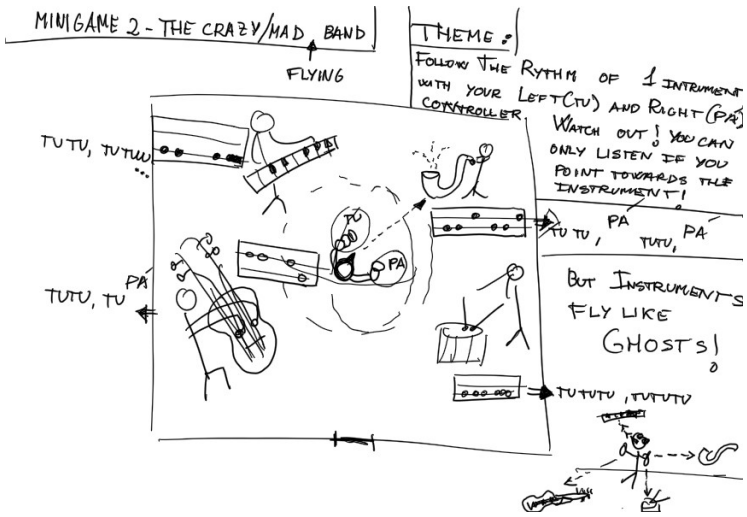

Figure 10.3: The crazy/mad flying band game sketch

In this game, high directivity instruments are being played. The player should point the Oculus controller towards the desired instrument to not lost track of it (due to high directivity) and listen it. The instruments are flying all over the scene, so the player must move continuously to listen to the instrument, which is emitting a rhythm she/he should repeat with the Oculus controllers.

The Ninja Boss

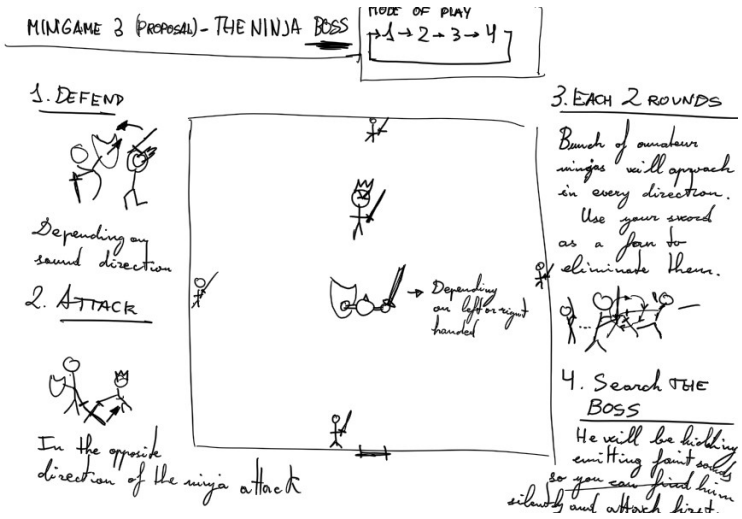

Figure 10.4: The Ninja Boss game sketch

Here the player must react quickly to a coming sword sound and use one controller to defend (shield) and the other to attack (sword) pointing rapidly in the direction ninjas are attacking or being prone/weak to be damaged. Incoming ninjas are from all directions, making a full immersive audio experience.

The Lost Orientation

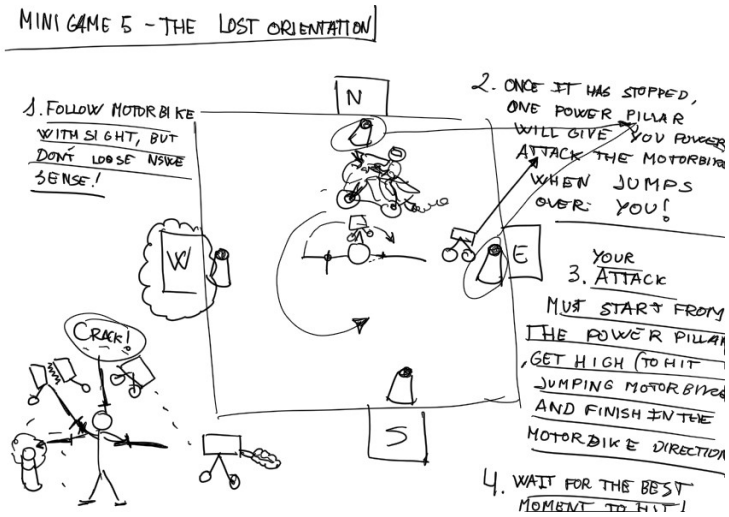

Figure 10.5: The Lost Orientation game sketch

A flying motorbike wants to hit you. You must kneel down to avoid it, and then trigger a power pillar in the opposite direction the motorbike wanted to hit you to destroy it.

The Flying clocks

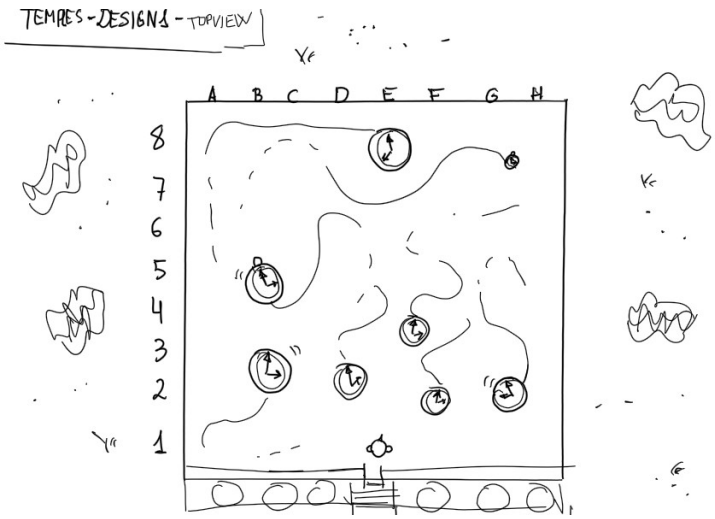

Figure 10.6: The Flying clocks game sketch

Player is in a chess table full of clocks. One of then "clicks" differently and you must pursue it and stay within his area for some seconds to catch it. For this game idea Harry Potter® flying keys scene and Harry Potter® quiddicth [57] game sequence was taken into account.

10.2 Design of haptic feedback additional device

To complement the sensation of immersiveness, an attachable device was intended to be made to compliment the Oculus controllers. There have been many studies related to how haptic feedback aids an impaired person [15, 58–60] and we wanted to design a specific compliment for the Oculus, not apart but integrated with it. First, we studied where the vibration motor is in the controllers, in order not to place and obstruct our additional device with [61].

Figure 10.7: Place where vibration motor is located within Oculus controller

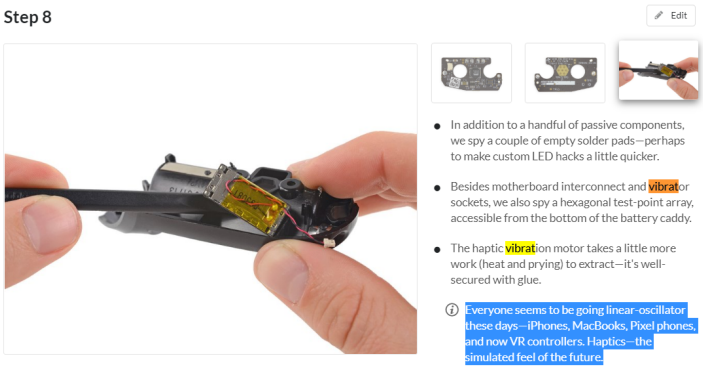

Figure 10.8: Vibration motor of the oculus controller

Then, after studying usual hand positions on the controller, we sketched on Fusion360 a "handle" for the Oculus controllers which would contain a secondary haptic feedback motor.

Figure 10.9: Natural position of hands on Oculus controller: Side view

Figure 10.10: Natural position of hands on Oculus controller: Back view

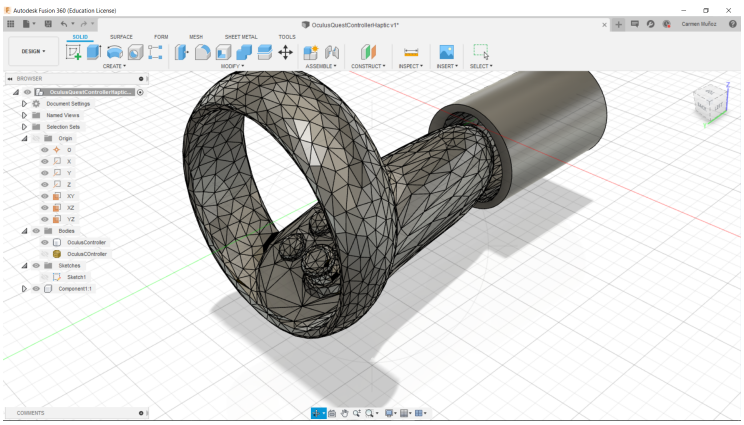

Figure 10.11: Handle v1 for controller in Fusion360

10.3 Discarded Artwork

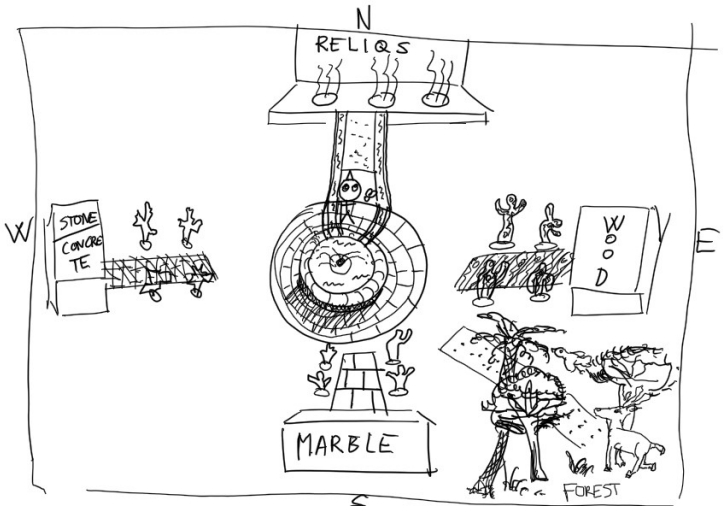

Figure 10.12: First sketch of the general world overview

Due to the unfortunate situation and not being able to get access to Oculus controllers, further development of this idea was stopped.

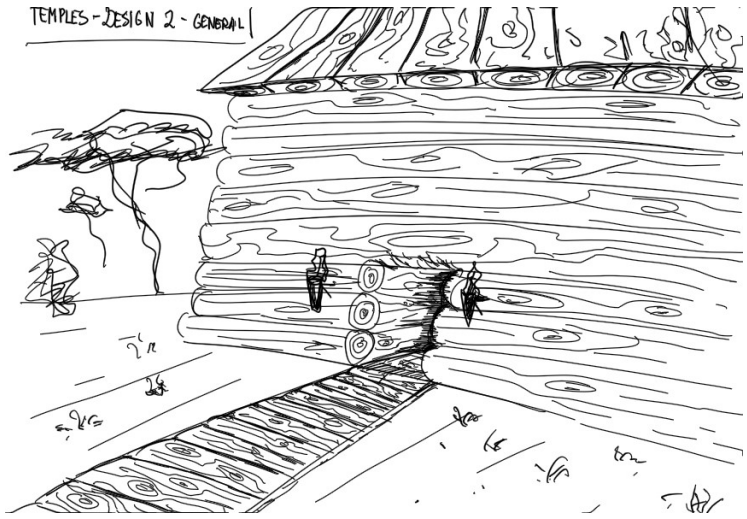

Figure 10.13: A general view of temple made of wood

Figure 10.14: Possibility of interacting with statues in the world

This was an idea to make the playground more interactive, so that the player could "transport" to other environments where a story focused on 3D audio about the statue (a frozen person in a material when madness was released) is told.