INTERACTIVE DIGITAL MEDIA

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Supervisor	Mark Nicholas Grimshaw-Aagaard
Students	Catja Agnstoft
	Martha Szlachetka Bomholt
	Sarah Emma Jensen
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Abstract

Danish

Dette speciale undersøger mulighederne for at udnytte lyd med henblik på at guide spillere igennem et computerspil i et forsøg hvori forsøgspersoner navigerer sig gennem en simplificeret prototype, der næsten udelukkende indeholder lyd. Lyd er bagud i computerspilsindustrien, da der mest fokuseres på det visuelle, dermed er det et interessant emne at udforske.

I dette speciale er der udført flere forsøg med brug af både kvantitative og kvalitative metoder for at finde ud af, hvilke lyde hjælper mennesker med at engagere sig og forbedre deres navigations færdigheder i en simplificeret opstilling af et computerspil. En prototype af et lydbaseret spil blev testet på ni ikke-synshæmmede personer i alt, hvoraf resultaterne peger på en forbedret evne til at navigere, hvis spillerne præsenteres for lyde i et 3D miljø, der er nemme at skelne mellem samt er genkendelige. Derudover, synes lydende også at forbedre engagement.

Specialet præsenterer en pilottest, der giver muligheder for yderligere forbedringer giver grundlag for et interessant og voksende forskningsfelt.

English

This thesis explores the possibilities of utilizing sound in order to guide players through a computer game level by testing how test participants navigate through a simplified prototype based predominantly on audio cues. Sound is not very advanced in the computer game industry because of the heavy focus on visuals, thus making it an interesting topic to explore. Within this thesis several tests were conducted using both qualitative and quantitative methods in order to discover what sound cues help people become engaged and improve their navigational skills within a simplified game setting. A prototype of an audio-based game was tested on nine sighted participants in total, of which results point toward an enhanced ability to navigate if players are presented with distinguishable, familiar sounds appearing in a 3D space. These sounds further seemed to enhance player engagement.

The thesis presents a pilot test wherein opportunities for further improvement provide the groundwork for an interesting and growing field of study.

Nøgleord: Lyd, spildesign, synshandicap, navigation, engagement, lydbillede, lyddesign, forsøg, 3D lyd

Keywords: Sound, game design, visual impairment, navigation, engagement, soundscape, sound design, experiment, 3D sound

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Glossary

Computer game - refers to all games, encompassing all platforms including console-based games, arcade-based games and handheld games, involving both digitally visual and audio-based games.

Visually impairment - refers to the decrease in ability to see, wherein the degree of reduced vision affects a person's daily life and the cause is not fixable with glasses.

Introduction

“Man likes to make sounds to remind himself that he is not alone” (Schafer, 1977, p. 256).

You start the game with a dark gray screen, though sound appears everywhere around you. A voice ahead says that an experiment has gone wrong, and you must find the key to exit. Your steps signal that you are walking on concrete, the sound reverberates from all sides, thus signalling a large, round room. You walk in darkness until you hear a sliding sound to your left signifying a door opening and as you walk in, your footsteps change from concrete to wooden flooring, the soft humming of computers envelop you and the growl of a monster appears to your right, turning louder by every passing second. You turn towards the sound of the enemy and feverishly start shooting, listening as the sound of bullets echo in the room until the creature ultimately gives out a last cry of death.

Sound appears and persists through the entire computer game. When you start up the game, you are greeted with the game developer logo, often accompanied by a sound or a musical theme which transitions to the main menu. At the main menu, each button, slider and dropdown menu makes a small click or beep, accompanying the visuals to let the player know they have indeed interacted with the button. Starting the game is met with a sound cue that signifies the player enters the game, whether this is a music piece, a simple click or a call of excitement from some non-diegetic entity. In the game, the player is met with sound from all directions; the ambient background sounds immerse the player in the game world, the growls and grunts of enemies warn them of potential dangers, the beeping of your health bar depleting, and the sound cue of your inventory opening.

Sound does not only immerse the player in the game world, it communicates with the player to tell them what state the game world is in and sound enhances the visual space presented (Breinbjerg, 2005; Jørgensen, 2006; Jørgensen, 2007). It can be used to set the mood of the game for example, birds chirping to signify a peaceful walk in the forest, a dripping faucet to create an eerie atmosphere within an abandoned house or even complete silence to add tension to the gameplay.

Michel Chion (1994) explains the value of sound as:

“(...) these sounds can be situated at different narrative levels, such as conventional background music(non-diegetic) and synch dialogue(diegetic) – while visual elements can hardly ever be located at more than one of these levels at once” (pp. 67-68).

Meaning, while there can only be one image on screen at the same time, sound can be added in abundance. Although a game can show a 3D-landscape, a game first and foremost adds a sense of depth to the game world once the player hears the sounds surrounding them (Sonnenschein, 2001; Röber & Masuch, 2005; Liljedahl, 2011).

In contemporary games, sound and music is oftentimes added purely for aesthetic reasoning with the functionality of setting the tone of the game or as narrative responses to the state of the game or player avatar. Mainstream games rely purely on visuals for gameplay and narrative, while audio can oftentimes be completely omitted if so desired. The field on audio design for games continues to grow slowly, albeit several nuances of audio design are still left to be explored by developers and scholars (Summers, 2016).

Kristine Jørgensen (2007) hypothesises that the reasoning behind a lack of research within the field computer game sound is due to the difficulty of analysing it. Sound, unlike an image, cannot be paused and studied per every centimeter. Wavelengths can be studied, as well as the composition of sheet music and how listeners respond emotionally towards a sound (Garner T., 2013). However, sound is instantaneous and situational. The context in which the listener experiences the sound as well as the emotions and thoughts which occur as a response can never be replicated (Jørgensen, 2007). Sound is also continuously present and persistent as it appears anywhere in the world. Even in anechoic chambers, which are created to absorb the reflections of sound and thus isolate sound waves from entering the room, does the body betray the listener by revealing sounds of heart beats, blood streams and the digestive system. As Schafer (1977) states:

> The sense of hearing cannot be closed off at will. There are no earlids. When we go to sleep, our perception of sound is the last door to close and it is also the first to open when we awaken. (p. 11)

Although visuals are prioritized in many games, sound serves more than a cue for the player that their gun is reloading. It is more than an ambient soundscape of wind and rain that signals the location to the player. It is more than the variants of growls from an enemy, informing the player of a nearby attacker. It is part of the gameplay experience.

Themes and problem

Ptolem's Singing Catacombs (NarWalEngineering, 2018) is an experimental grid-based action-adventure game made for blind people, using a syllable-based echolocation system to inform the player what type of object is in front of them. The player’s heartbeat signals what

direction they are facing, the sound of footsteps tell the player how large the room they are currently residing in is, and ambient wind plays in either the player's left or right ear to signal an opening in the game level layout (Walters, 2018).

After reading the report wherein the developer of the game explains the thought process of the audio-based game, we were inspired to delve into current research and explore the landscape of audio-based games. Our first interest and driving force was to make a game that was accessible for people with visual impairment similar to *Ptolem's Singing Catacombs,* although with the interest of simplifying the controls to remove the syllable-based echolocation and avoid using grid-based movement. However, after researching and reviewing current audio-based games available on the contemporary game market as well as researching online on how blind people or people with visual impairment played computer games, we quickly realized that said blind gamers seemed more likely to play mainstream games. Though many audio-based games are available, the varying qualities and lack of larger, commercialized games make the blind gamers seek towards larger titles populated by rich soundscapes. Even if the audio-based games were created specifically for visually impaired gamers as their target group, visually impaired gamers are more likely to seek towards the genres where they exploit gameplay features in order to make the game accessible for themselves (Huiberts S., 2010; Van Tol & Huiberts, 2006; Vandal, Russo, & Sacks, 2012). As Shelby Travers, a blind gamer, states in the documentary *Gaming Blind* (De Toni & Nault, 2018):

When it comes to accessibility in video games, Steve echoes the thought of the game developers I met at the game accessibility conference: Gamers with disabilities want to play the same games that their friends are playing. That means mainstream games. (19:09-19:23)

Based on our findings, we instead decided to change the focus on the project to avoid solely converging on accessibility in games.

Instead, our interest therefore shifted from exploring the scope of an audio-based game towards how to immerse and navigate the player in a world of only sound. Or rather, our interest shifted from the target group, the visually impaired, to the medium, as audio-based games. As Mats Liljedahl (2011) states regarding hearing as an underused sense in computer games:

> What happens for example if we reduce graphics and visual stimuli and instead build the gaming experience more on sound and audition? What would the effect be if you had a computer game with only an absolute minimum of graphics and instead a rich,

> varied and gameplay-driving soundscape? Potentially such a game would be immersive in other ways and give different types of game experiences compared to more traditional, graphics-based games (p. 34).

There is a large potential in audio-based games to create unique sound experiences that have yet to break through the game market. For now, the largest target group for audio-based games remain visually impaired gamers, and as mentioned above, even the visually impaired gamers are more likely to turn to mainstream games of higher production quality than the available accessibility games (Huiberts S., 2010).

However, audio-based games can create interesting gameplay as players' imaginations are stimulated and the players must rely on hearing rather than sight to pass through a game level. By making players rely on hearing rather than sight, it can inspire methods for creating new and innovative game mechanics targeted not only to the visually impaired community but to sighted players as well.

Furthermore, an interesting opportunity arises to explore the undercurrents of technology and the market for audio-based games by encouraging another target group to interact with the media. While visually impaired players interact with mainstream games, the opposite effect could be investigated where sighted players could be inspired to interact with audio-based games traditionally created for the visually impaired. By incorporating a new, larger target group, an increase in demand as well as improved quality due to a larger player base might result in audio-based games turning to a mainstream genre which could benefit visually impaired players in the future.

Limited literature is found of research done on audio-based games and conducted experiments have mainly been in relation to providing immersive and accessible experiences for visually impaired players as well as using it for educational purposes to improve their navigational competences (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014) Grabski, Tan, Zigrand, Weller, & Zachmann, 2016; Allain, et al., 2015). Only a limited amount of experiments regarding how sighted people interact with audio-based games exists, although those performed proved that sighted gamers indeed found audio-based games enjoyable, both finding the mechanics innovative and the complexity of the challenges enjoyable (Targett & Fernström, 2003; Jäger & Hadjakos, 2017). However, the games presented were simplistic due to familiarity or limited range of features, and hence the experiments provide opportunities to create more complex challenges to engage sighted users. Therefore, researching possibilities in utilizing audio as a game mechanic presents interesting groundwork for a thesis.

For the master thesis, we are interested in researching the possibilities behind producing a game with limited graphics. With this, we intend to explore how to present a concept of a world and a system to players using only audio to navigate through the game, creating an experience, which also aims to provide accessibility features for the visually impaired. Therefore, we seek to answer the following question through this thesis: How do certain audio cues engage and guide players within an audio-based computer game with limited graphics?

Visual impairment

While this project will not focus on visual impairment and accessibility, it would still be beneficial to look at how visually impaired gamers interact with computer games as well as the current state of audio-based games available for the visually impaired. When interacting with mainstream games with limited accessibility features, people with visual impairment must adapt habits in order to play their favourite games.

Much can therefore be learned from how blind people interact with games, use and react to sound cues. In the documentary *Gaming Blind* (De Toni & Nault, 2018), a blind gamer named Emily Miedema is introduced by playing Mega Man 3 (Capcom, 1997) and navigating the game world with aid of high color contrast and using sound cues to e.g. tell her when she is in a safe room before the boss battle. Gamers with visual impairment draw on many tools in order to play through the games, such as memorizing layouts and enemy patterns, as well as using lights and sound cues. Therefore, studies relating to how visually impaired navigate through game levels will still be reviewed and discussed in order to understand what techniques could be applied to make audio-based games enjoyable for sighted users.

In relation to Interactive Digital Media

In the study program Interactive Digitale Media, no classes focus on audio design and the effects audio provides for user experience with the field inhabiting limited presence within the curriculum. While topics on level design, user engagement across platforms and consistent narration are wide spread across the semesters, most of the classes focus on the emotional impact and how users interact with the haptic and visual feedback provided. It can be argued that audio design and game design should be kept separate as the composer, programmer and designer emerge from different fields. However, as more games are produced every year from smaller production teams, it therefore proves that the optimal course is to have some basic understanding within several fields to minimize errors of design. For example,

the creator behind the farming-simulator *Stardew Valley* (ConcernedApe, 2016) and the creator behind roleplaying game *Undertale* (Toby Fox, 2015), are creators who gained praise in gaming communities due to their innovation and originality in their games while developing these games single-handedly. It is further optimal to have at least base knowledge of the other disciplines within game development to minimize miscommunication across the different teams, and in regards to audio, ensure that the audio is used to fullest extent and remains consistent in its use throughout the entire game.

Audio is equally as significant as visuals regarding emotional impact, narration, and user experience. Audio within computer games inform the player of where they are, what interaction they can or have already performed and they aid in easing the player into the game system and world. They further serve as a layer of aesthetic to the gameplay and as feedback to objects that can be troubling to visualize. For example, when the player fires a gun, they hear the sound of a shot to inform them that the gun has indeed gone off even though they might not see a bullet (Alves & Roque, 2011; Jørgensen, 2006).

Furthermore, beyond the scope of computer games, audio provides feedback on additional interactive digital media such as websites, mobile applications, and other software.

With this paper, we aim to encourage the creation and exploration of games that prioritize audio above visuals. Either balancing audio and visuals or shifting between the two sensory modes offer the groundwork for innovative and unique game experiences. Therefore, we further encourage other studies and our own to invest in researching audio as enhancement for user experience and investigate further into the field of audio.

Overview of thesis structure

This thesis documents the theoretical research and analysis regarding player engagement and navigation within a virtual space. The aim of the thesis seeks to develop an understanding regarding how audio cues aid sighted participants through an audio-only world, as well as provide a framework for future researchers with a similar interest.

The following chapter delves into the history of sound design from when the first computer game which included sound was released with the purpose of understanding how the audio field of contemporary computer games has evolved. The chapter investigates the evolution of computer games playable by visually impaired players, thereby examining which computer games were initially available for consumption of visually impaired gamers.

A chapter regarding what computer games inspired the direction and production of the experiment regarding how audio cues provide a navigational tool for players is presented, discussing a variety of computer games with affective data which shaped the game mechanics and choice of soundscape presented.

A literary review presents and reflects studies of concepts and experimentations within the field of audio. The reviews delves into a thematic framework regarding the effects sound enables on cognitive perception, the different modes of listening and how sound influences immersion and navigation within computer games.

The subsequent chapter then explores the methodological framework applied through the course of the thesis, examining the various methods performed in order to create a framework for the thesis.

The chapter following after involves the theoretical framework, consisting of concepts regarding the function of sound in computer games, the identification of sound, non-verbal sound signals, concepts of audio-based games as well as the theory of flow to assert the understanding of player engagement. The theoretical groundwork serves to examine and understand the results of the empirical experiment. The chapter following involves the design process with underlying thoughts and considerations for both prototypes developed. Afterwards, the results procured from the experiments are presented as well as evaluated with considerations towards concepts identified within the theoretical and literary framework. A discussion afterwards establishes the strengths and weaknesses within the study and enables future studies to develop further with the presented framework.

Definitions of terminology

Computer game

Within this thesis paper, the term computer game will function as a reference towards all games, in which platforms of arcade-based games, mobile, handheld games, and console-based games are included as there will be a variety of games, available on a variety of platforms, mentioned throughout the paper. An alternative term that could be considered is *video games,* which emcompasses several platforms and genres as well. However, the term video specifically seems to connotate visual feedback and therefore excluding any audio-based games. Therefore, computer games favor the notion of a digital game playable on any console and of any genre, which can further encompass both visual as well as audio-based games.

Visual impairment

In this thesis, visual impairment applies as a reference towards a decreased ability to see. According to the World Health Organisation (2021), the term visual impairment is classified within two groups consistent with distance vision impairment and near vision impairment, wherein it is further divided by degrees of visual acuity ranging from mild to blindness. An alternative description explores visual impairment as any degree of impairment regarding the vision which affects the person's life and which cannot be fixed through equipment such as glasses (Sapp, 2010). This term appears more preferential due to the fact that the initial intention of the prototype is presenting a game with limited graphics which people affected with blindness can play. The mechanic and game level is designed towards the impression that everyone could participate. As such, people who can increase their ability to see through glasses will not experience the same challenges within our prototype as people experiencing blindness would. Therefore, for the purpose of the thesis, visual impairment will refer to the decrease in ability to see, wherein the degree of reduced vision affects a person's daily life and the cause is not fixable with glasses.

History of game sound design

Before delving into the current field on audio-based games and audio design, a review of the historical and cultural development of sounds in computer games will be explored in order to understand the influences behind the contemporary usage of sound in games. Much can be learned from looking at the past of sound design, and we hope by looking at the technological, social, and economical influences on sound in games, we gain insight into the current game market as well as empathy to better improve the user experience of future games.

Sound to video

The first computer games released in the 50s came without sound, and it was not until 1972 when the American company Atari released the game *Pong* that sound made its entrance into game development as a feature (Collins, 2008; Scarratt, 2018). Pong only contained three types of simple beeps—a beep for hitting the paddle, a beep for hitting the bottom or top of the screen and a deep beep that signified losing the game (Summers, 2016). Back then, these simple beeps were revolutionary and the purpose of the sounds were unmistakable. The sounds added an emotional level to the simple arcade game, and provided feedback to the player in regards to whether the ball had hit their paddle and would fly in the opposite direction or if they should expect a game over (Jørgensen, 2011). Pong

not only introduced sound, but popularized arcade games and soon after all arcade machines featured electronic sounds of varying kinds. The sounds had to be loud to attract customers who passed as well as drown out the sounds from neighbouring machines, so the player could hear what was happening on the arcade machine they were standing by (Collins, 2008; Collins, 2016). However, it was the hardware technology of the arcade machine which set the sound requirements for what was possible to make. It was difficult to program on the early machines and oftentimes, composers would write down the note sheet which would then be programmed directly into the system using binary code (Collins, 2016). Therefore, many of the earliest arcade games consisted of simple sound effects with no background music accompanying. Most of the arcade games only had an introductory sound as well as a game over noise, possibly with a few important, albeit limited sound effects for gameplay.

Sound chips were integrated into arcade machines circuit boards by the 1980s which allowed more elaborate sound effects for gameplay feedback. The sound chip held three sound channels along with one noise channel made for sound effects. However, when a sound effect was played, it would play over one of the sound channels, so composers had to consider what sounds they wished to prioritize as they had a limited amount of space (Collins, 2016).

Due to the rise in popularity of arcade games, a surge in production pushing entertainment hardware for the home occurred, with each hardware technology offering a unique sound system with a variety of available sound effects. By the 1980s, the first personal computer was introduced by IBM, although its original intention was regarding business practices. However, due to a rise of successful personal computer competitors, IBM sought to make games accessible on the personal computer to attract more customers. The major competitors of PC were Apple Inc. with its personal computer originally designed for casual users, and the Commadore 64, which had been specifically designed for gaming. The Commodore 64 offered enhanced graphics and a synth-chip with waveforms and filters for sound design which surpassed any other product available at the time (Collins, 2016; Jørgensen, 2007).

In 1985, the Japanese game company Nintendo introduced their Nintendo Entertainment System, also referred to as NES, to the western market. The console offered better graphics and a better quality of sound with the Nintendo sound chip, which allowed more types of waveforms in sound and therefore changed the landscape of sound in games. However, sound was still set aside till the end of game development as graphics and gameplay were prioritized. There continued to be a limited amount of space on the console, and game

developers had to be innovative with the few tunes which were available on the hardware. Games like Super Mario Bros. (Nintendo, 1983), Legend of Zelda (Nintendo, 1986) and Final Fantasy (Square Enix, 1987) became instantly popular among gaming audiences as the sound in these games not only informed the player of events on screen, but connected them with the game world itself (Jørgensen, 2007).

New advanced sound systems by synthesizer manufacturers were being produced and distributed onto the market. The Musical Instrument Digital Interface, also referred to as MIDI, was a soundcard capable of holding 32 simultaneous voices and 128 present instruments. Along with it came the General MIDI standard, which was a template for the 128 instruments on the soundcard. This meant that an instrument chosen by the composer would play back as that instrument on multiple MIDI devices. The MIDI itself did not contain audio, but was instead used as instructions which told the computer how to read and produce sound along with the intended pitch and volume. As the MIDI was a string of codes, the file size was very small which was an advantage for games with limited amount of space left over for sound. However, the issue with the MIDI was that not all hardware devices had the same sound quality, and so sounds would come out differently depending on what device they were played on and the volume and sound quality would vary greatly between sound cards. To combat the varying sound quality, composers oftentimes had to make different versions of the same music piece or sound effect so it could be compatible across the different hardware systems. However, this was a tedious process and tremendous work to the composers, who would have to change all the versions of the same melody if the original sound piece needed to be iterated (Collins, 2008; Collins, 2016).

Sound changes player's perception of space

Up until the 1990s, the MIDI system continued to be the standard of sound technology in game development. However, when CD-ROM technology took over and developers started to migrate towards more realistic soundscapes, the MIDI standard was soon discarded. The CD-ROM ensured that the sound would be the same across all hardware as well as offering better quality for both sound and graphics (Jørgensen, 2007).

Along with the integration of the CD-ROM technology came the evolution of surround sound in games. This allowed players to perceive sound around them in 3D games, which in turn allowed developers to enrich game environments with sounds behind and beside the player, while they had only been able to present sound directly in front of the player in the past. Additionally, while surround sound was popularized in game development, First-Person Shooter games, also referred to as FPS games, emerged as a new genre containing games

such as Wolfenstein 3D (id Software, 1992), Doom (id Software, 1993), and Quake (id Software, 1996). Wolfenstein 3D especially set the standard for FPS games as the first FPS game within the genre. The game's soundscape built on the narrative of the game, where an American soldier is trapped by Nazi soldiers in a German stronghold. Within the game, American national melodies and Nazi anthems are played along with the gameplay, thus creating a context for the gameplay as well as immerse the player in the game world. However, only one sound effect could be played at a time within the game (Weske, 2000; Jørgensen, 2007).

The game Doom built on the ground of Wolfenstein and used their sound to inform the player of the location of an enemy, as well as what type of enemy was near the player. Each enemy had their own distinct sound for attacking, being injured and dying, and the volume of the enemy's sound would decrease or increase depending on the distance to the player. Multiple sounds could be played at the same time and ambient sound effects were included to immerse the player in the game world (Weske, 2000; Summers, 2016). 3D stealth games such as *Thief: The Dark Project* (Eidos Interactive, 1998) similarly used surround sound to inform the player where enemies were positioned in relation to the player avatar. The game system would additionally inform enemies where the player was located depending on how much noise the player made from walking on a specific type of flooring.

The Microsoft DirectX application was released to standardize sound and ensure that all sound would follow the instructions of the software enabled instead of the hardware technology. An element of DirectX called DirectMusic overhauled the MIDI standard so it became more flexible in terms of which instruments should be played and ensured that all sounds were the same across all personal computers (Collins, 2008; Jørgensen, 2007).

Brief history of audio-based games

As the first computer games released had little to no sound, it would take decades as well before audio-based games became an accepted, albeit niche genre in the landscape of gaming. However, between the early decades of computer game development, the visual impairment community explored other game genres and though the games were not originally intended with visually impaired in mind, the games nonetheless became popular within the community. This is still seen in contemporary games, which contain accessibility features though the visually impaired community were not the intended target group. For example, games such as Animal Crossing: New Horizons (Nintendo, 2020), Grand Theft Auto Series (Rockstar Games, 1997-), Call of Duty: Black Ops (Treyarch, 2010) etc. (Van Tol & Huiberts, 2008; Vandal, Russo, & Sacks, 2012).

One of the genres popular within the visually impaired community was text-based games, also known as Interactive Fiction Games. These games consist of an interface made up of text-only and the player interacts with the game by typing in commands which the game in turn reacts to. The first text-based game was Colossal Cave Adventure, also oftentimes referred to as Adventure, released in 1976 by Will Crowther. In the game, the player explores a large cave-system through simple two-word text commands such as “Enter cave” and “Go left” (Jerz, 2007). The game’s source code was later found and expanded upon and inspired countless iterations and many similar text-based games. Despite text-based adventures requiring reading and their popularity taking place before accessibility features, such as enlarged font size or different font-families existed, the feature of screen-reading allowed visually impaired players to follow along. Furthermore, as the entire game world and players’ actions were descripted as text on the screen, visually impaired players missed no information presented by the game (Vandal, Russo, & Sacks, 2012). However, the popularity of text-based games slowly declined in the 1980s as game graphics became better, resulting in players naturally migrating towards games with visuals presented.

Before the first text-based game was released, Atari released the first audio-based game in 1974 as a handheld arcade game named *Touch Me*. It consisted of a small screen with four buttons which would light in a pattern accompanied by tones to which the player had to repeat the pattern (Atari, 1974). Visually impaired gamers could easily play the game by relying on their hearing to press the correct buttons.

Later audio-based games were created with little to no visuals and purely informing the player of the game world through sound. Many of these stem from smaller companies such as Somethin’ Else that developed *Papa Sangre* (2013), and Dowino that created the game *A Blind Legend* (2015) or as free, open-source projects, where popular games are converted to audio-games to be accessible for the visually impaired community, such as *AudioQuake* (Atkinson, 2013).

Figure 1. The Atari hand-held arcade game “Touch me” released in 1974.

Summary

When looking back at the history of the simple beginnings of game sound and its evolution throughout the ages, we understand that the direction in which audio was developed has been heavily influenced by contemporary technological standards. As space had always been limited on many software devices, sound was oftentimes the last feature to be implemented and composers most often had to think creatively with what limited tones and space they were offered. With each iteration of game hardware, manufactures, and game developers are striving to reach higher levels of realism in games. In the 70s, *Pong*’s sound design was seen as realistic despite only containing three simple tones, while in the 80s, Wolfenstein 3D could only play one sound effect at a time but was still regarded as being a revolutionary game in immersing the player. In contemporary games, entire orchestras are

hired to produce soundtracks for games and multiple tracks run at the same time. As such is the case with Resident Evil 7: Biohazard (Capcom, 2017), where an orchestra was hired to score the game like a horror movie while sound was integrated to create an eerie atmosphere to unnerve the players (Morimoto, Kojima, & Usami, 2017). When computer games were first produced, sound was merely used to inform the player of the game state. Now, sound is also used for aesthetic quality, to immerse the player, and involve them in the overall game world.

Inspiration

When coming up with ideas and figuring out which direction we wanted to go in with the prototype for this project, we looked at a variety of different computer game genres to find out how sound was utilized within them. We knew that we wanted a shooter game but we still wanted to look at other genres as well to see how they introduced sound to the player. In this chapter, we will talk about some of the games we tested and took inspiration from.

A Blind Legend

As we knew we wanted to create a computer game primarily reliant on audio, we looked into what audio-based games that already existed. One of the games that we came across that we were also able to try out was the game *A Blind Legend*, which was developed by Dowino and released in 2015 for Android, iOS, Microsoft Windows, and MacOS. *A Blind Legend* (Dowino, 2015) is a fully auditory game with no graphics in which the player controls a blind knight who along with his daughter sets out to rescue his kidnapped wife. As the knight is completely blind, the only way to navigate is by following the voice of the daughter who will continuously let the player know which direction they need to move in. As the player moves through the game, they will encounter different enemies that they need to defeat by listening to their movement. In order to defeat the enemies they will have to find out which direction they are coming from, and swing their sword in that direction and if they miss, they will take damage as the enemy attacks them. In the beginning of the game, the player hears the voice of a narrator who tells them how to control the character and how to fight, which makes the learning of the game easier.

There are many different sound cues in this game; most of them environmental sounds that lets the player know what sort of environment they are located in, for instance a town or a cave. Furthermore, the daughter is never quiet for too long and will always let the player know if they are moving in the wrong direction and if they need to turn in order to reach the objective. Whenever there is an enemy, they are also constantly making sound so the player can hear where it is located in order to defeat it.

The sound cues in *A Blind Legend* (Dowino, 2015) are all very helpful, some are informal and some help immerse the player in the game world. However, we found that while playing, the environmental sounds would sometimes almost drown out the voice of the daughter,

which made it very difficult to navigate as the player is constantly in need of the feedback of her voice in order to know which direction to go. From this experience, we learned that it was important to balance all sound cues so the most important sounds would not be drowned out. However, we ended up not adding very many environmental sounds to our prototype, as we wanted to keep it simple and potentially less confusing for the player.

Apex Legends

As mentioned above we knew very early on that we wanted to make the prototype a shooter and so we began looking into the shooter genre. The main games we looked at here were first-person shooters as we wanted to know how sounds were used in this perspective. One of the games we looked at within this genre was *Apex Legends* (Respawn Entertainment, 2019).

Apex Legends (Respawn Entertainment, 2019) is a free-to-play, player versus player battle royal, developed by Respawn Entertainment for Microsoft Windows, PlayStation 4, Xbox One, Nintendo Switch, iOS, and Android. In this computer game the player teams up with other players in teams of either two or three. Each player chooses a character—referred to as a Legend—from a line-up. Each character has their own unique set of abilities that can help both the player and the team fight their way to victory along with the guns they can find within the game. Once the characters have been chosen the players are put in an arena wherein they have to fight 40-60 other teams, depending on whether they are in teams of two or three. As the players fight each other, the arena shrinks over time as a storm takes over the outer parts of the arena in order to discourage hiding from the enemy and encourage fighting. The last team standing becomes the champion.

As *Apex Legends* (Respawn Entertainment, 2019) is a player versus player shooter, most of the sounds are informational to the player. Apart from the more common sounds, like shooting, walking, bullets hitting, picking up objects, etc. the player's character will give them additional information when various things are happening to them. The characters inform the player whenever the arena starts shrinking as getting caught in the storm damages the player and can eventually be fatal. A big alarm type of sound will also go off for a couple of seconds when this happens. Additionally, the player will be informed by their character whenever some of their abilities are charged and if they are getting shot at by another team. Another important sound in this game is the sound of footsteps coming from another team. These can be a bit tricky as the game does not differentiate between the sound of teammates' footsteps and enemy footsteps but once the player is in a fight the sound of

footsteps are incredibly helpful to know whether the enemy is to the player's right or left, or above or below. However, the vertical sound is more difficult to hear than horizontal sound.

All of these sounds are very informational and helpful for the player to become the champion. There are, however, some additional sounds in *Apex Legends* (Respawn Entertainment, 2019) that are not necessarily informational and if the sounds have not yet been learned they can be very confusing, especially because the environment is very tense and the player is constantly listening for enemies. These sounds are ambient sounds and world sounds that are there to create a certain environment that helps immerse the player.

Borderlands 3

Another game we looked at within the shooter genre was *Borderlands 3* (Gearbox Software, 2019). *Borderlands 3* is an action role-playing first-person shooter developed by Gearbox Software and Gearbox Studio Québec for PlayStation 4 and 5, Xbox One and Xbox Series X and S, Microsoft Windows, and MacOS.

Borderlands 3 (Gearbox Software, 2019) takes place in a foreign world where the player has to fight through an apocalyptic-looking environment filled with hostile enemies. The player starts the game by choosing between four different characters that each have a set of abilities that will help the player defeat enemies and advance in the game. Each character has four different skill trees, in which the player can buy additional skills to their own liking every time the character's level increases. In *Borderlands 3* (Gearbox Software, 2019) the goal is to go on missions to defeat enemies and acquire loot to become stronger.

The sounds in *Borderlands 3* (Gearbox Software, 2019) are mostly player activated, meaning that they are heard when the player interacts with the game world and the user interface. Sounds are heard with each button the player pushes if that button has a function. However, in this game it was the environmental sounds that caught our interest. Every interactive object placed around the game world has a unique sound depending on their function. As loot is important in this game there is a variety of loot boxes all over the game world ranging from chests and safes to large rocks and skulls that hide things beneath them, each with their own sound. The sounds are very low and non-disturbing and cannot be heard until the player is standing almost right next to them. Another object that had the same effect was vending machines that were placed around the game world in which the player could buy new weapons, ammo, and medicine. As we wanted our prototype to have limited graphics, we found the way that these sounds were implemented very helpful in letting the player know that there was something close to them that they could interact with without

distracting them from the more important sounds like hostile enemies being nearby. Furthermore, we found some inspiration in the concept of the vending machine as a way of acquiring new weapons. However, we ended up not implementing them into our prototype as we decided that acquiring new weapons was not as important in the earlier stages of our game as we wanted to keep it simple.

Animal Crossing: New Horizons

Outside of the shooter genre, we tested the game *Animal Crossing: New Horizons* (Nintendo, 2020) which is a life simulation game developed by Nintendo for the Nintendo Switch. The aim of this game is for the player to develop a comfortable life on a deserted island by decorating it, upgrading buildings, and inviting villagers to live on it. The sounds in *Animal Crossing: New Horizons* (Nintendo, 2020) range from interactive and ambient to music. There are many sound inputs hitting the player all at once, as there is no way of adjusting the volume of them separately. All the sounds are connected in one track and can only be turned up or down all together on the console itself. However, though it is sometimes slightly difficult to hear certain sounds, there are many valuable sound cues in the game.

One of the sounds we found particularly helpful was the error sound, which is heard every time the player tries to e.g. fish and dig where they cannot do so. Additionally, we took note of the music in the game, which changed every hour, making it very clear, once you had learned the sounds, whether it was morning, afternoon, evening or night.

For this game we also found Ross Minor on YouTube who is a blind person who makes videos about how he plays typical audio-visual games without being able to see. He has made a video talking about how he plays *Animal Crossing: New Horizons* only through sound. In this video he talks about which sounds are helpful to him and how he can navigate using such things as footstep sounds that sound different depending on the type of ground he is walking on, or following the water to find his in-game house. One thing he mentions is how each item in the game has their own sound, which helps him identify exactly what he is doing (Minor, 2020).

Stardew Valley

Similar to *Animal Crossing: New Horizons* (Nintendo, 2020), we also looked into *Stardew Valley*; a computer game developed by Eric Barone under the alias ConcernedApe. The game was initially only released on Microsoft Windows in 2016 but has since been released

on Linux, macOS, Nintendo Switch, PlayStation 4, PlayStation Vita, Xbox One, Android, and iOS. *Stardew Valley* (ConcernedApe, 2016) is a farming simulator in which the player inherits a farm in a small town that they have to rebuild by growing crops and acquiring farm animals, which they have to take care of. Throughout the game, the player will make friends with the locals and open up more locations for them to venture into as well as build their skills in various activities such as fishing, mining, and farming.

In *Stardew Valley* (ConcernedApe, 2016) there are many informational interactive sound cues as well as environmental sounds and music. However, unlike *Animal Crossing: New Horizons* (Nintendo, 2020) these can all be adjusted separately, making it easier for the player to control what they are hearing at any given point in the game. Additionally, the player can also control the sound level of their own footsteps, whether or not sound plays when they are in a dialogue as well as turning off the sounds the animals make. The many different sound categories gave us a little bit of insight into what sounds might be important for information and which could potentially be left out in our prototype.

Valheim

Another game we tested outside of the shooter genre was *Valheim*, which is a survival role-playing game developed by Iron Gate Studio and released in 2021 for Linux and Microsoft Windows. In this game the player plays a viking and starts in a mostly untouched world full of forests, meadows and swamps. The goal of the game is to create your own experience by leveling up skills, building structures, hunting, killing enemies, etc. The player basically creates their own goals whether that be upgrading every weapon and all crafting supplies to the maximum level or defeating all the world bosses.

Valheim (Iron Gate Studio, 2021), if not changed, plays constant sound through music and ambient sound. Additionally, it contains a lot of interactive sound cues that are very helpful in identifying what the player is doing. However, it does not distinguish between whether the player is picking up e.g. wood or stone, which can be slightly confusing. Something we found interesting was that as the player explores the game world they come across different types of biomes whereas each biome has its own sound. This makes it easy for the player to navigate the world and figure out what types of materials and enemies they might encounter in the area they are exploring.

The testing of all of the above games gave us further insight and ideas for how we could best utilize sound in our prototype. The sounds we weighed most important were the

informational and interactive sound cues as well as the ambient sounds that could help the player find landmarks to navigate between and thereby identify where they were located.

Literary review

The following chapter serves as an introduction to the theoretical framework which outlines and acknowledges areas of research and study the thesis itself is built upon.

This literature review will discuss the potential of sound as a tool of navigation, including the effects sound has on cognitive perception and how sound contributes to realism in gameplay. Additionally, it includes extensive research into the functionality of sound in games and illustrates the sensory perception of sound in relation to human hearing to understand the significance of audio in games and hence creating the groundwork for the theoretical foundation of the thesis. Although this thesis seeks to understand how sound functions as a navigational tool with no visual attachment, a brief discussion of immersion is supplemented, thereby presenting discussions on what additional factors affect player engagement.

The effects of sound on cognitive perception

Through the literature, there is consistent evidence that audio extends the perception of the visual beyond the scope of what is presented. Schafer (1977) proposed that sound served as a symbolic reference to the environment and the objects they represented, such as aircrafts informing people of the growing access to remote places or industrial noise of machinery serving as a symbol of power. The sensory experience of sound attaches images and thereby symbolism to the source of the sound. Within cinematography, Chion (1994) asserts the usage of sound tricks the viewer's perception of what happens on- and off-screen as sounds rouse the viewer's curiosity and adds depth to worlds unseen. Therefore, even if the visual embodiment of the sound remains hidden, sound can inhabit spaces without raising questions as to its origin. As Sonnenschein (2001) states: "One of the most surprising audiovisual phenomena allows the audience to believe that whatever sound is synchronized to the image is the sound being emitted by that image" (s. 35).

Therefore, audio and the visual create a complex and dynamic relationship, wherein using audiovisual dissonance where audio and visuals portray different things and therefore carry the viewer's perception of the image beyond what appears on the screen. The listener's associations and emotions are dependent on the sound as the sound itself controls the assumptions towards the image presented (Liljedahl, 2011). Garner T. (2013) found that

despite the image visibly shown, it was the sounds connected to the image which represented the associations behind it, hence enforcing the intended purpose of the image. For instance, despite seeing the image of maggots on a corpse, it is the sound of buzzing flies which creates the assumptions of a decaying body (Garner T. (2013).

Jørgensen (2007) found that when gamers played without sound, the gameplay turned problematic and a feeling of absence insured and the virtual world itself seemed to disappear. Furthermore, research by Grimshaw M. (2007) showed players losing a sense of immersion and enjoyment of the gameplay when sound was reduced. Garner T. (2013) additionally adds to the argument that removing sound causes the game world to feel entirely virtual opposed to realistic.

Across the studies on sound design and its effects on human perception, there is therefore consistent evidence that sound enhances the visuals within computer games while the absence causes reduced enjoyment and engagement in the gameplay. Furthermore, sound augments and enhances other stimuli, such as visuals, wherein it is then sound which sets player expectations and contributes to our reactions from the source of the sound or what it leads up to (Cunningham, Grout, & Picking, 2011). Therefore, sound provokes other sensory stimuli and human psychology to react as seen in cases of sound intensifying the feeling of fear (Garner, T., 2013).

Walter-Hansen and Grimshaw-Aagaard (2020) argue that in order to grasp the concepts of what lies in our visual saliency, our sensory stimuli model perceptual hypotheses of environments emerging from our sensations and cognition. This we draw from our sensory experience, such as the sense of hearing, of environments to distinguish the external world. The idea of sensory experiences emerging into a perception of the external world draws back to the school of pragmatism, wherein Dewey (2005) argued that experiences emerge from their relation between experiment and consequence. Thus, the experiment with a sound and the consequence, argued in terms of sensations, creates the experience and perception of our visual salience. Perception in this context is purely referential towards the psychological and socio-cultural understanding of our environment rather than the temporal-spatial position of the sound. Several researchers reflect on the effects the sensory stimulus of hearing has on our external perception of the world wherein we interpret sounds from previous experience which in turn reflects how we value images presented (Chion, 1994; Liljedahl, 2011; Summers, 2016). In a similar vein, Garner T. (2013) provides the interesting argument that it is not only our memories, but our present interactions, state-of-mind and current environment which establishes our interpretations of the sound.

However, a sound simply does not exist; it emits from a context or a source from which our interpretations constantly change. Ballas and Mullins (1991) provide a contrasting argument to the understanding and reaction as sound depends on the circumstances in which it occurs, and it is the context in which the sound is heard which manipulates the viewer's interpretation on how to perceive the presented sound: "*For example, a policeman investigating a burglary might hear a metallic click and wonder if it is a gun or a door latch*" Ballas & Mullins, 1991, p. 216). As such, the context in which the sound is emitted sets the atmosphere and expectation of the interaction. Our perception of presented sound reflects how we perceive the relationship between the meaning of the sound to its physical or virtual source (Garner, 2013). For example, in a computer game, hearing the sound of buzzing flies within a kitchen versus in a dark cave can yield different results of how the sound is interpreted.

Our interpretation of sound presented within computer games arise from our personal perceptions of the sound and their represented sources in the salient world. As such, each person perceives and understands sound based on their personal experiences in a physical or virtual context while also taking their immediate surroundings into account.

Therefore, sound proves to be a highly important tool for game design and development, albeit it is important to understand the consequences of its usage as it lingers on people's perception. A lack of research to solidify this claim suggests a lack of understanding in terms of how audio should be used in its current state, whether to drive the plot or simply as a mechanic. Further research into the manipulation of audio as well as the context the audio is presented in could encourage innovative design choices within the computer game industry.

Examination of listening as a game function

Classification of sound is another highly iterated field within study of sound that provides challenges in how to categorize sound and the usage of it. A precise classification of sound is hindered by the varying usages of sound in computer games. Therefore, this section presents a brief overview of the classification methods of sound, specially the categories of listening as well as classification of sound roles within games. Mentioned literature presents an outline of the various methods and their development as reference.

The varying degrees of purposes audio serves in games point toward an illustrative range of terminology for describing auditory functions, and it is an ongoing process that is

continuously iterated upon. Based on literary findings, the classification of sound can be separated into two states: the act of listening and the purpose of sound itself regarding game functionality.

Chion (1994) identified three modes of listening of *semantic-, reduced-* and *causal* listening to understand the cause and meaning behind a sound. He argued that causal sounds were most common to listen for, as they contained information of the sound source itself. However, causal listening is also described as the most deceptive of the listening modes to be influenced by unrecognizable sounds or contexts and thus leading back to the above argument regarding sound manipulating the listener's perception.

Jørgensen (2007) briefly presents a fourth mode of listening, from Chion's *Audio-Vision* (1994), called *Acousmatic listening*, wherein the listener hears a sound without seeing its source, albeit Chion uses the term later in his book *Audio-Vision* as a property for a sound itself in cinematography rather than an active mode of listening. The acousmatic listening is further established to merely intensify the causal listening as it forces the listener to seek the source of the sound.

However, Chion's three modes of listening only provide a groundwork for understanding the ear's perception of distance and spatial relationships towards the context of the sound. They lack the psychological impact in which sounds affect the listener's emotional state.

An interesting addition of a fourth mode of listening called *Referential listening* is provided by Sonnenschein (2001), wherein sound affects the listeners with the context and thus the emotional and dramatic meaning, which can either be instinctive or related to a socio-cultural context. This eliminates the lack of a listening mode concerning the psychological perspective of sound.

Similarly, Grimshaw & Schott (2007) expand the modes of listening from solely relating to cinematography and ensuring a relevance towards computer games by incorporating a fourth mode called *navigational listening*. With navigational listening, the player listens to sound to guide them through the game world. This mode seems reflective of the causal listening with the dissimilarity consisting of the source of sound itself guiding players through game levels rather than simply listening for the source.

The fascinating phenomenon regarding the navigational mode of listening is how it differentiates itself from the other modes in its functionality. A common agreement in the literature where listening is defined as an active action where the listener actively selects, remembers and responds to the sounds presented. On the other hand, hearing is identified

as a passive, unintentional activity, where the listener receives information without necessarily responding to it (Chion, 1994; Sonnenschein, 2001; Jørgensen, 2007). Therefore, Chion's original modes of listening as well as Sonnenschein's addition of referential listening are activities, where the listener reacts and responds to the sound. However, navigational listening contracts this by interacting with the player regarding navigating them throughout the game world. The sound is not only something the player reacts and responds to, but something they cooperate with, thus making it more than an active way of listening, but potentially a reactive, or interactive way to engage with sound.

Whether Chion's original modes of listening should be used regarding the usage and understanding of computer game sounds, Grimshaw & Schott (2007) propose that by introducing new terminology the method will be adapted towards a new medium and suggesting that the player will shift between the different modes of listening depending on the context and the player's experience.

Jørgensen (2007) provides a dissociating argument wherein she explains that two of Chion's listening modes of reduced listening and semantic listening do not translate properly to a computer game context. Due to the perceiver rarely listening to the content of the sound as well as attempting to understand the semantic value of the sound, other authors are therefore better suited to explore the relationship between sound and listener.

Droumeva (2011) provides a dissimilar argument by suggesting six new modes of listening depending on the historical shift of quality, technique and function the game sound provides, thus prompting the thought whether Chion's modes of listening are perhaps outdated when moving towards the computer game medium. However, Droumeva's six modes of listening seem more directed towards the relationship between the listener and the sound itself, rather than contents of the sound itself. Further explorations into a sound's cause and meaning regarding gameplay could yield innovative results in how we react and interact with the sound as well as the techniques we use to listen for them as individual sounds rather. While Jørgensen (2011) argued that reduced listening was unnecessary in the computer game context, gamers with visual impairment have shown to listen for the properties of the sound itself to succeed in gameplay, as it then depends on the context presented and what the player needs in order to complete the game level.

Sound, immersion and navigation

Through the literature, there is consistent evidence that audio enhances the feeling of immersion by providing navigational listening and consequently enhancing the player's enjoyment. The term immersion itself is used thoroughly by game developers and scholars when discussing player engagement and gameplay experience, albeit the purpose and goal of immersion seems to vary across the field. As immersion seems to be a subjective, ambiguous term, several definitions and methods of calculation of it seem to have arisen throughout the decades.

In an attempt to define immersion, Brown & Cairns (2004) conducted a set of interviews to understand gamers' experiences when playing computer games. Based on their results, they describe immersion as an experience shaped by degrees of involvement with the game and in order to immerse the player further into the experience, the involvement barriers must be passed in a scale of *engagement*; *engrossment* and *total immersion*. While the first two barriers are described as time investment and emotional attachment to the game, total immersion is described as the player feeling present within the game world itself and losing spatial and temporal presence to reality.

In the vein of Brown and Cairns' three levels of immersion, Gordon (2007) proposed a model of Digitale Game Involvement wherein sustained involvement with the game leads to engagement and internalization of gameplay and environment, resulting in the player reacting instinctively. In it the state of deep involvement that the borders of the game disappear and the player becomes part of the environment, which Gordon uses as a metaphor for immersion.

The thought of internalization of gameplay and environment relates to Czikszentmihalyi's (2008) theory of flow, where a gradual learning curve will lead to engagement and involvement with the product until the user is absorbed in their interaction. The theory of flow is oftentimes used to depict the optimal state of immersion, as is Brown and Cairn's Total Immersion, where the user experiences a distortion of time and space in their absorption with the experience. This perspective on immersion is endorsed by several other researchers who agree that immersion stems from the player being absorbed into the game world and becoming less aware of their surrounding environment (Jørgensen, 2011; Huiberts S., 2010; Keeffe, 2011).

However, when the player can only achieve immersion through internalization of gameplay and through repetition and effort become accustomed to the game's rules and environment,

the amount of players reaching a state of total immersion depends solely on the players themselves. Game scholars and developers can attempt to create a flow experience in their gameplay, but must accommodate the different psychologies and skill levels of the player as the theory of flow only considers the activity itself and not the psychological state of the player who performs the tasks. Furthermore, by slow incorporation into the game world through repetition and learning, there is no consideration for fast, in-the-moment immersion which can occur when a player experiences a strong emotional impact such as fear or anxiety. Thereby, Ermi & Mäyrä (2005) provide a counteracting argument; "(...) the answer is that immersion is a many-faceted phenomenon with different aspects that can appear and be emphasised differently in the individual cases of different games and player (p. 7)". They argue that Brown and Cairn's three levels of involvement lacks the consideration of the different modes of involvement when different players hold individual preferences to games and genres. They further point out that flow-like experiences in digital games should be seen as fleeting experiences called 'micro-flow' or 'game-flow', as players can easily exit and enter the flow-state depending on the game they are playing. Instead, they suggest that immersion is divided into three different areas depending on the context and the player interacting with them, called *sensory immersion, challenge-based immersion,* and *imaginative immersion*. The three areas overlap as various factors in-game can contribute to all three areas, whereas the gameplay itself is a temporal experience which the player engages with according to their own psychological and social understanding.

Based on Brown and Cairns, Jennett, et al., (2008) conducted a series of experiments to measure the subjective level of immersion which in turn measured immersion as a personal experience. The results proved that immersion was provoked through both positive and negative experiences, hence immersion is invoked from emotionally-charged experiences with the game. Jennett, et al., (2008) further state that immersion is the result of a good gaming experience, and not that it is the requisite to obtain a satisfactory experience.

As such, many factors affect the player's sense of immersion and enjoyable experience, such as ensuring emotional investment wherein the player feels engaged in the gameplay. Factors such as detailed soundscapes can stimulate the imagination and evoke emotional responses from the player's perception of the game world (Liljedahl, Papworth, & Lindberg, 2007). Toprac & Abdel-Meguid (2011) conducted an experiment to examine how manipulation of volume, timing, and sound source can evoke fear and anxiety within players. They determined that acousmatic sounds invoked fear and anxiety in players, and when presented with a visual without any sound, the visual object did not invoke the same sense of fear as if it had been accompanied by a sound. Therefore, they suggest that sound

enhances the fear response, and has a similar effect on other emotions. Additional findings by Garner T. (2013) also suggest that sound facilitates emotional investment, as a series of experiments were conducted in measuring participants' reactions to sounds invoking fear. The results revealed that game sound has significant impact on players' emotional responses, although further revealing that player experience and completion time of a game level also impacts whether they would perceive a sound as threatening.

Therefore, coherent evidence suggests that sound impacts emotions, and the emotional investment influences player attention and their perception of the environment which consequently leads to immersion. It is through the affected psychological state of the player that creates the illusion of the game world as real due to emotions distorting the player's sense of external presence (Nacke & Grimshaw, 2011; Grimshaw & Schott, 2007). Garner T. (2013) posits a counter argument from which he describes that it is not immersion into virtuality which affects player emotions, but rather that by evoking authentic and genuine emotional responses, the player will become immersed in the virtual environment. It is engaging gameplay, narrative, and precise timing which stimulates emotional responses that causes the game world to seem more immediate and immersive.

An additional consistent trend which persists across literature is that the gameworld is perceived as real through immersion. When the player experiences immersion with a game, it is described that they lose spatial-temporal sensation and hence the lines between reality and virtuality are blurred (Brown & Cairns, 2004; Ermi & Mäyrä, 2005). Furthermore, Jørgensen (2006) identifies that it is through integration of realistic sounds to gameplay features and naturally occurring sounds which correspond to the environment they manifest in that contributes to player immersion. For example, when the player is injured with a knife, a sound of cutting through flesh accompanied with a groan of pain ensures realism in the gameplay.

In Alves and Roque's (2011) article on guidelines for sound design, they argue that realistic sounds are not necessary to create a rich and immersive sound experience. Rather, sounds which attempt to portray realism can oftentimes be viewed as uncanny. Furthermore, when realism fails to be portrayed, the experience itself is degraded. Instead, sound should be designed to influence emotions and the perception of the game world as well as use sound to associate actions with events. Another issue arises from the implementation of realistic sound to a game when the game itself does not take place in a realistic setting. For example, sci-fi or role-playing games, where developers cannot produce accurate sounds of a zombie groan or a dragon roar because they do not exist in the real world. Instead, developers

should rather focus on the soundscape being perceived as naturalists in the virtual game setting rather than realistic.

Garner T. (2013) suggests that Hollywood-esque sounds of e.g. a shotgun or footsteps in the snow, which have been exaggerated for visual and narrative impact, have saturated how those sounds are perceived by the audience as unrealistic when registered in reality. He further argues that immersion does not only arise from a set of characteristics which define reality and instead proposes the approach of affected realism, where the player is immersed due to stimulation of emotions which occur in reality. Based on a series of observations on how visually impaired players interacted with audio-based games, Garcia and de Almeida Neris (2013) compiled a set of guidelines for audio-based games, wherein one of the guidelines involves describing a sound as accurately as possible to represent its realistic counterpart. However, if there is no accurate, realistic representation of the sound, an artificial sound can be used although the sound must be thoroughly described to the player beforehand (Jäger & Hadjakos, 2017; Garcia & de Almeida Neris, 2013). Nonetheless, an accurate representation of sound is only a characteristic of the reflection of reality on virtuality. The natural presentation of the sound in terms of room acoustics, reverberation, and sound propagation based on the environment are also important factors to consider when representing the sound in a virtual space to attain perceived realism and immerse the player (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014; Sánchez, 2017; Grabski, Tan, Zigrand, Weller, & Zachmann, 2016). Specifically in audio-based games, reverberation, and room acoustics are imperative for the player to understand the location of the player avatar and their surroundings when most or all visuals are absent. Subsequently, reverberation and sound location affect players' perception of the environment and improves the realism of the game world (Allain, et al., 2015).

Echolocation as a navigational tool

From the above argument, another aspect of immersion arises from spatial information of sound source locations and player awareness of space within the game world. While accurate spatial sounds provide an element of realism to the gameplay, further enlargement of the game world occurs through 3D navigational audio from which the player feels engaged (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014). Contrary to this, Sánchez (2017) argues that audio realism and navigation counter each other as complex architecture of game levels can affect reverberation and create a loss in perception, although easy

navigation can make the game levels too simple for the player to complete, resulting in player boredom. Exploring the above argument, Jäger & Hadjakos (2017) observe that when creating an audio-based game, a simplified architectural structure of the game level provides improved navigation and orientation for the player. Admittedly due to players easily colliding with obstacles, albeit this factor can be dependent on how difficult game developers wish their game to be.Connors, Chrastil, Sánchez, & Merabet (2014) conducted tests on whether blind participants could navigate unfamiliar virtual environments from which they observed that users created complex spatial cognitive constructions of the layout to navigate through. Similar tests of navigation on sighted players indicated that through 3D binaural auditory cues, participants could easily navigate through game environments and that the optimization of auditory spatial information enhanced immersion (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014).

However, studies using virtual echolocation mechanics on blind participants found that the technique improved participants' cognitive spatial mapping of game environments and layouts (Andrade, Baker, Waycott, & Vetere, 2018; Andrade, Waycott, Baker, & Vetere, 2021).

Echolocation itself is an ability found in bats and dolphins, as well as humans who can learn and harness the technique in order to identify location, size and material components of objects surrounding them. The ability appears as both passive and active hearing, where a person either passively listens to sounds surrounding them or actively clicks with the tongue or claps their hands, thereby orientating themselves. Through active echolocation, the person listens for the echo of their generated sound which in turn informs them of their surroundings' properties (Wu, et al., 2017). Thaler and Goodale (2016) found that blind people who use echolocation prove more independent in mobility than visually impaired people who do not. However, due to societal stigma, blind people feel discouraged from performing echolocation in public spaces (Thaler & Goodale, 2016). Therefore, using echolocation as a game mechanic can be used to train and engage visually impaired people to be comfortable echolocating, while it can provide a unique experience for sighted players.

Andrade, Baker, Waycott, & Vetere conducted a test in 2018, wherein visually impaired participants explored a virtual house through the use of echolocation. They found that although participants were able to navigate the game layout, they first needed to become familiarized with the echolocation technology in the game. Participants informed that the technology lacked the tactile feedback occurring when they were echolocating in the physical world, while it was further noted that each person's method of echolocating varies as people perform clapping while others mouth-click for surrounding feedback. Therefore,

translating the technique into a virtual space proves difficult as it diminishes key elements of echolocating in physical spaces.

Additionally, experiments conducted on untrained sighted participants revealed that they were able to detect walls in virtual reality (Pelegrín-García, De Sena, Van Waterschoot, Rychtáriková, & Glorieux, 2018). Dodsworth, Norman, & Thaler (2020) found that with enough training in echolocation, sighted people can navigate complex virtual layouts and reduce collision interaction through audio cues, albeit adjustable parameters for echolocating intensity could prove beneficial and representative of how participants would mauver in the physical world. In general, limited research on sighted people in virtual settings seems available, though this could be due to the amount of training sighted participants must undergo in order to practice the ability of echolocation in a virtual setting.

A limited variety of computer games attempt to introduce the premise of passive echolocation as a game mechanic, wherein the player listens to the environment in order to navigate through the game levels. Games such as Lurking (Runneraway Games, 2014), Dark echo (RAC7, 2015) and Muffled warfare (Gattai Games, 2018) use sound to make game objects appear before the player, albeit the game still presents visuals to showcase how the sound reverberates throughout the game level without informing the player of the surrounding objects properties. Furthermore, players continuously rely on visuals above audio to complete the game levels as the echolocation seems merely used for graphical stylization rather than mechanical purpose. Nonetheless, echolocation proves an interesting field of study as well as a unique mechanic in computer games to improve orientation and mobility in audio-games while further encouraging player imagination of how the game world appears through complex perception of object location.

Observing immersion as an effect in computer games

As noted upon previously, a significant number of studies view immersion as an effect occurring from player enjoyment, wherein they lose sensory perception of the temporal and spatial surroundings. However, Bălan, Moldoveanu, Moldoveanu, & Dascălu, (2014) state:

To be accessible and appealing to visually impaired people, audio games should fulfill the following specifications: A high level of immersion and attractiveness to motivate the user to advance in the game. (s. 111)

Essentially, immersion itself is viewed as a perquisite for playing a game and it is through immersion of the game that enjoyment occurs rather than through enjoyment and attention towards the game which enables immersion. However, this logic observes immersion as a measurable quantity which, when increased, encourages and engages players, rather than above arguments which observe immersion as an ambiguous effect that occurs from several factors such as realistic sound properties and flow in gameplay. Studies have attempted to measure immersion quantitatively through questionnaires, albeit these have been criticised for reducing immersion (Larsson, Västjäll, & Kleiner, 2003). Instead, analysing the psychophysical and physiological reactions towards players' perception of presence seems to correlate towards a measurement of immersion. Experiments with recordings of emotion and body language as well as eye tracking showcase methods wherein player engagement becomes measurable by setting specified parameters and categories for degrees of immersion (Grabski, Tan, Zigrand, Weller, & Zachmann, 2016). One of such experiments conducted by Jenett et al. (2008) identified players with increased eye movement to be less or non-immersed than players with less eye movement due to distractions, while those with decreased eye movement were focused on a task which encouraged immersion. This method of measuring immersion however cannot be applied to all game genres, as games with fast-paced gameplay require increased eye movement from the player engagement. Furthermore, while eye tracking is a variable method for understanding players' engagement with visuals, it is difficult to measure audio-based games or how sound affects players' engagement.

Alternatively, returning to Tropac and Abdel-Mequid (2011) as well as Garner's (2013) research in how sound evokes emotions, researchers could instead look at the emotional impact on how games affect players to measure player engagement from which immersion stems. Frome (2007) identifies ecological emotion where players react physiologically to game environment and events e.g. leaning to the side in real life as the player avatar looks around a corner, or screaming out of fear in a horror-survival game. From observing how players respond emotionally and physiologically to in-game stimuli, researchers can explore alternative methods for measuring player engagement, which can lead to immersion. However, each person interacts and interprets games differently depending on previous experience and player personality (Grabski, Tan, Zigrand, Weller, & Zachmann, 2016). For example, a player experienced in first-person shooters might be more accustomed to quick thinking and gameplay, while an inexperienced player might be more tense, hence leading to subjective and varied results. Therefore, in order to utilize this method of exploration, parameters and conditions for player interaction with the game must be set, as each player's interaction and interpretation of the game will be different.

Conclusively, there seem to be several arguments within the literature that immersion is enabled through several factors such as emotional attachment to the narrative, accurate soundscapes, and enhanced navigation through auditory cues. The role of immersion differentiates within a computer game depending on the purpose of its requirements, whether it is supposed to enhance emotional involvement or navigation through the game levels.

Theoretical framework

Sound effects in computer games are most often not the highlight of any video game. In fact, it can be argued that if the sound in a video game is good it is barely talked about because it is almost unnoticeable to the player in the way that they hear it and know that it is there but it is not distracting. It is simply there—enhancing the visual experience of the game. Bad sound, however, especially in games such as shooters where the player relies on the sound to know where the next enemy is, can become a hot topic of discussion. Knowing that there is an enemy close by but not being able to hear where they are due to bad sound design leads to a very frustrating experience. Therefore, video games like shooters that rely on sound cues even if they are minor need to have a well-developed sound design.

Most games let the player know when they are interacting with objects such as picking things up or shooting a gun through sound. The player can hear when they walk or when they stop but most of these sound cues are usually enhancing a visual experience, meaning that not only can the player hear it but they can also see that these things are happening. In fact, according to James R. Parker and John Heerema (2008), most people rely more on visuals than they do sound (2008). But what happens if you take the visuals away and leave the player with a game fully reliant on sound?

Audio games are still a bit of a niche and they are mostly developed for visually impaired people. This makes sense considering people who have no visual impairment rely so heavily on visuals and therefore there is a possibility that audio games do not attract much attention from this group of people. However, most, if not all, audio games can be played by all hearing people.

In this chapter we will look into different theoretical frameworks, examining how audio is used in video games and what purpose it brings to these games and how players identify sound signals. We want to look at how audio-based games can engage players and what other experiences audio games can bring to the table.

Functions of sound in computer games

Sound in computer games have a number of different functionalities. Most notably, sound is used to enhance the player's immersion in the game world through sound effects, ambient noise, and music. Karen Collins (2013) describes in her book Playing with Sound, how

interactive sound expands the borders of the virtual screen. She gives an example of the game *Dead Space 2* (Visceral Games, 2011) that through surround sound had players curious to explore areas that they could not yet see because it emitted sound. Additionally, the sound cues would even make the players turn their body not only in the game but in real life to figure out where the sound was coming from. Furthermore, she describes sound in games as being an extension of the player in that it spreads throughout them and creates a sense of presence whereas the visuals of a game are simply something outside of the player (Collins, 2013).

As well as immersing the player, sound is also used as a way of giving feedback to them. In Mats Liljedahl's chapter Sound for Fantasy and Freedom, he talks about the role that sound can have in giving feedback. Liljedahl specifies that sound effects have an important place in giving the player feedback and states that they are "absolutely necessary for feedback to the players of computer games" (Liljedahl, 2011 p. 32).

Identifying sound

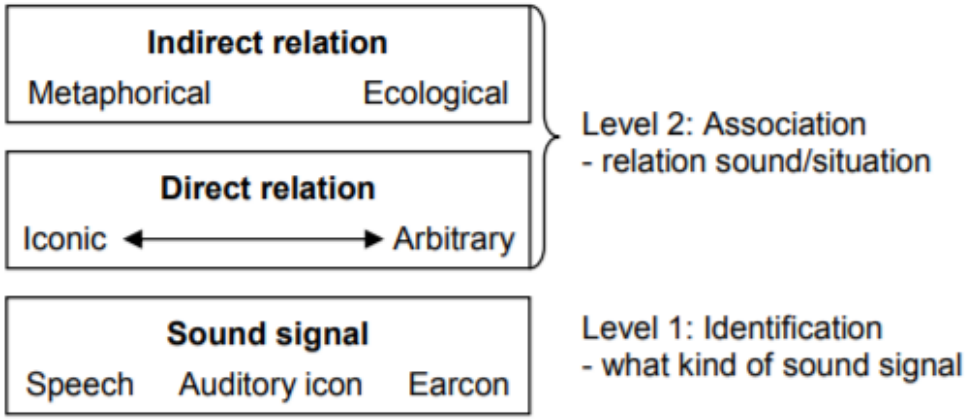


Figure 2. Keller and Stevens' taxonomy as presented by Jørgensen (2007) (ref.).

In the virtual world sound is often used to communicate to the player that they are manipulating something on the screen whether it be walking, pushing buttons, or using abilities, etc. However, there are different ways of relating a sound to an interaction in order to best communicate with the player. In her dissertation Jørgensen (2007) talks about Peter E. Keller and Catherine Joanna Stevens' taxonomy of auditory signals which organizes auditory signals and their references. The lowest level of the model relates to the

identification of the sound signals. The sound signals can be identified as either auditory icons, speech, or abstract sounds — referred to by Jørgensen as earcons. The two higher levels relate to how the player interprets the sound signals. This is separated into *direct relation* and *indirect relation*. Direct relation means that the sound signal does not need to be learned but the player knows what the sound refers to. The relation between the sound and that which it refers to can be either iconic or arbitrary. If it is iconic it means that it is natural as in the real life version of the object making the sound in game would make the exact same sound. Whereas arbitrary means that the relation between the object and the sound has been manufactured in some way (Jørgensen, 2007).

Indirect relation means it is a bit more abstract and is about understanding the sound through other related or unrelated things — a so-called surrogate. Jørgensen uses the example of the trash can on one's computer:

> "The file removal programme is represented by an image of a trash can. The image of a trash can becomes then the surrogate of the image of the removal programme. However, since an image of a removal programme would be very abstract, the surrogate trash can is added instead." (Jørgensen, 2007 p. 66).

This type of relation can both be ecological and metaphorical. If the surrogate has no direct relation to the referent whatsoever, it is metaphorical. An example of that could be the trash can example mentioned above as both "surrogate and target are equivalent in appearance and/or function" (Keller & Stevens, 2004, pp. 3). Furthermore, if the relation is ecological it means that the surrogate coexists within the same world as the referent (Keller & Stevens, 2004) i.e. using the sound of crackling fire as surrogate for a campsite or a wolf's howl as a surrogate for nightfall.

In this paper we will not be discussing indirect relations further as they are not often used in computer games (Jørgensen, 2007) and we will not be using them in our prototype.

Non-verbal sound signals

The lowest level of Keller and Stevens' model (Jørgensen, 2007)l as mentioned above can be identified as auditory icons or earcons. Auditory icons are natural sounds that do not have to be learned. They are intuitively recognized by the player and are nonverbal. However, if verbal sound is used as a sort of background noise to imply human presence, it can be referred to as an auditory icon (Jørgensen, 2007). Footsteps are an example of an auditory

icon as most people would already know the sound of footsteps from their real life and thus, do not have to learn it.

Earcons on the other hand are sounds that need to be learned as they are more abstract. Earcons can be more difficult to place as they can turn into auditory icons over time or have a foot in each camp, if you will. Jørgensen (2007) gives the example of magic. Magic is not real and therefore, the sound of magic is not something we know from experience, however, over time magic has become a more common phenomenon within the fantasy world and thus, the sound of magic has become more commonly known and does not have to be learned.

Audio-based games and visual imparity

Audio-based computer games are still a bit of a niche as sound in computer games is still slightly overlooked in comparison to the time spent on the graphics. According to Valter Alves and Licinio Roque (2011) the missing guidance on sound design is so bad that developers are not adding the appropriate amount of sound in their games, leading to a lacking experience. Alternatively, when developers do want to integrate sound in their games they have to go with what they feel is best, which can be detrimental to their results (Alves & Roque, 2011). However, audio-based games are great for visually impaired people as they mostly rely on audio and have very limited visuals and if the game does have visuals they are usually not needed in order to play the game but more of a filler for those who have any level of vision.

According to Oana Bălan, Alin Moldoveanu and Florica Moldoveanu (2015) audio games help visually impaired people with navigation and orientation in that they can transfer what they have learned in the game to the real world. Additionally, audio-based games help build cognitive maps of the virtual space the player exists in, which further improves navigation. However, it is important to limit the number of audio cues sounding simultaneously as it can cause difficulties and confusion with navigation (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014).

Flow

It is almost impossible not to talk about the flow theory first introduced by psychologist Mihaly Csikszentmihalyi when diving into the world of computer games. The theory of flow represents the balance needed between skill and challenge. It is important to keep this balance for the player of a game to stay in a flow state. If the player does not stay in a flow state they will, according to Csikszentmihalyi become either bored or anxious. In order to balance skill and challenge, we must continuously match the player's ever increasing skill with new challenges. However, it is important to not make the challenges too difficult or the player will feel inadequate, leading to anxiety. Likewise, it is also important to not make the challenges too easy or the player will become bored (Csikszentmihalyi, 2008).

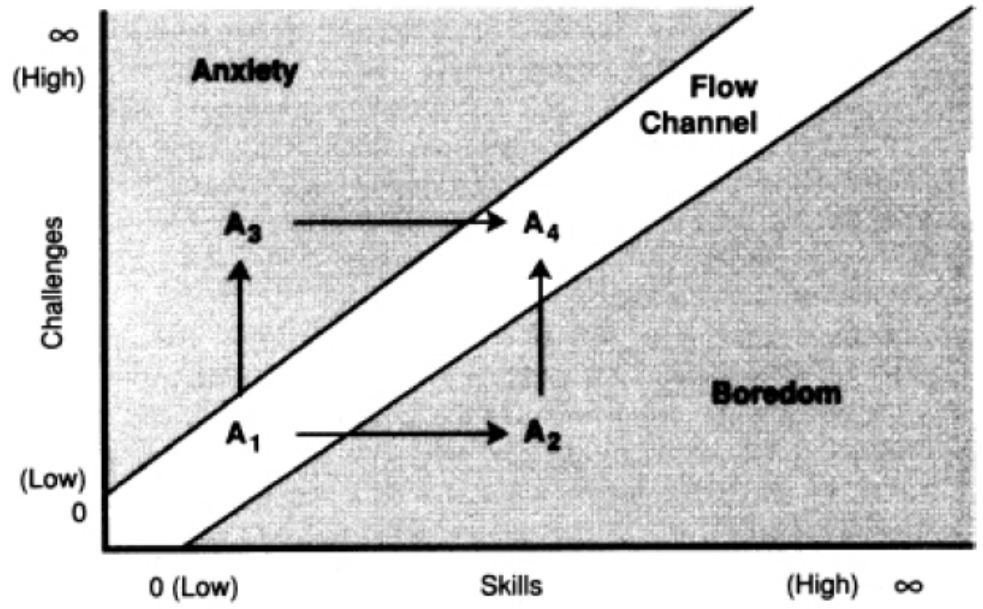


Figure 3. Flow theory model (Csikszentmihalyi, 2008).

This balance is explained in the figure above. A1 is the starting point, where the player first learns what skills are needed and what challenges they face. Once they have learned they can either slip into A2, which is boredom – too high skill for the challenges – or A3, which is anxiety – too difficult challenges for the player's skill level. From there the only way the player can return to a state of flow is by either facing more difficult challenges (if they are in A2) or increasing their skill level (if they are in A3). This will take the player to A4, which is back in flow. However, from here the player will face the same situation again, constantly needing to improve themselves in order to face the more difficult challenges ahead (Csikszentmihalyi, 2008).

It can be argued that in a computer game setting it is not only up to the player to keep themselves in flow by not rushing too far ahead and running into too difficult challenges but also up to the developers to not let the player face too difficult challenges too soon. This can be done by e.g. limiting where the player is allowed to move, which is a common method in computer games.

For the prototype designed for this project, we will be limiting the player to the A1 phase, keeping them in flow by not introducing too many unfamiliar sounds and challenges as they are still in the learning stage of navigating the level and recognizing sounds.

Methodology

Navigation in audio-only computer games using first-person perspective has proven challenging due to users having to rely on their sense of hearing to localize game objects and navigate within a virtual world (Jäger & Hadjakos, 2017). According to Bălan, Moldoveanu, Moldoveanu, & Dascălu (2014) “the development of navigation skills is based on alternate remaining sensory modalities, such as hearing and touch.” (p. 109).

For instance, its orientation and mobility is the main issue for visually impaired people, audio games are according to Bălan, Moldoveanu, Moldoveanu, & Dascălu (2014) a reliable training modality that improves orientation and mobility through an accessible and enjoyable approach. Merabet and Sanchez has previously demonstrated that a ludic-based approach to learning to navigate the unfamiliar settings ultimately helps the user build a reliable spatial cognitive map of the virtual world environment (Merabet and Sanchez In Balan, 2015).

For this project two experimental pilot test concepts were developed, with the intention of exploring how players perceive audio-based cues and how they engage and help players navigate through a virtual environment. The sounds are meant to closely resemble various types of environmental sounds that are commonly found in our surroundings.

Participants

Using an experimental design, a total of nine people participated in the test sessions from two countries (Denmark and the United States). In regards to gender five of the participants identified as female (F: 5), four as male (M: 4), and none as other nor specified differently (O: 0). The mean age was 30.33 years with a median of 25 (range 22-54 years), and 100% reported playing video games at least 1 to 2 hours a week, while 44.44% reported playing 13+ hours a week or less.

Based on pilot testing, it was determined that the sample size of roughly three to seven participants per test session would be required to determine an effective outcome from the gathered data. Once the required number of participants completed the experiment, data collection ended for the specified session. Six of the nine participants had previously taken part in the first test session and therefore had prior experience with the concept. Participants were not required to complete multiple experiments per session and instead each experiment contains a single focused sample. However, there were some that wanted to

replay the game during a session. Furthermore, an informed consent was obtained from all participants in all experiments before any and all testing was to be conducted.

Procedure and design

The tests were conducted in separate locations and carried out between 27th of April and 2nd of May 2021 (i.e., first test session of the prototype; build version 0.5), and 4th of May and 9th of May 2021 (i.e., second test session of the prototype; build version 0.8). Participants played a shooter computer game where the main objective was to find a key that would be spawned randomly into one of three rooms—never in the player's starting area.

The first version of the game was built upon and reprogrammed from an existing commercial game called *FPS Microgame Template*. The original version of the commercial game, FPS Microgame, is a small, fully functional game that was designed to help get people started with Unity. The experimental version that was tested was adjusted by the group, and the game consisted of one level with four different sections (also referred to as rooms). The game was only playable on computers running Windows.

Experiment setting

As previously mentioned, sessions were conducted in different locations whereas sessions that included participants participant B, participant D, and participant E were conducted online using Discord and recorded with OBS, and participant A, participant F, participant G, participant H, and participant I were conducted offline at the respective facilitators home office. A session with participant C was conducted online as well as offline. The online session made use of Discord, a server that first launched in 2015 as a means for people to communicate while playing PC games together. This was combined with the software *Open Broadcaster Software* (abbreviation *OBS*) and is a free and open-source cross-platform streaming and recording program launched in 2016. Sessions conducted offline would use either the aforementioned approach or would use the Xbox Game Bar to record audio and video during the sessions, which is a Windows 10 tool designed to help capture gameplay.

However, before any recording can proceed it is important to establish an informed consent with participants that recordings of the session are allowed. If the participant agrees then the

recordings would begin as soon as the demographic section of the interview is being handled. Then again at the beginning of each gameplay round and however long freeform commentary is taking. Lastly, a recording must be captured for the interview done post-gameplay. Thereby, having either one long recording of the whole session or if sectioned, into three to four separate recordings ready to be processed. Once recordings for all test sessions had finished the group would meet and discuss any insights gained from their respective facilitated sessions. These would be based on observations written down during or after a session. Shortly thereafter, we would review the recordings and take notes of any points of interest or commonalities found. The recordings would be transcribed later into the project.

For the setup for each individual test session of the prototype, the facilitator from the group would recommend to their participant that they use headphones while playing the computer game. Furthermore, the participants needed to have a mouse available to be able to fully control the player character as it was part of the character movement controls. Additionally, they needed a functional keyboard or at the least a keyboard that had functioning W, A, S, and D keys to control the player characters in the direction of forward, backward, and sideway to the left and right. Moreover, for the interview section to proceed as expected the participants needed to have some type of microphone such as headphones with a built-in microphone, an external microphone, or their computer needed to have an internal microphone. If none of the above cases were possible the interview could have either proceeded over the phone or have been conducted in person, if the participant was comfortable with that scenario. In regards to the recommended software used for all sessions, which was Discord, the participants would need to download the application and create an account beforehand as this was necessary for the facilitator to view their screen during gameplay. The participants needed to download a zip folder uploaded to Google Drive or Discord containing the appropriate build version of the prototype for the specified test session. Furthermore, it should be noted that all participants that used their own personal computers experienced issues with anti-virus software notifications that would pop up when they first attempted to open the file. This was possibly due to not having a publisher name attached to the build.

Once done comparing and categorising the most important elements we would then begin sketching and re-designing the level based on the feedback. For example, it became clear

that participants were unaware that the level could possibly be angled and not a straight passage—it had not occurred to any of the participants that the level would be angled. We decided therefore to move the rooms into a position that would account for people's preconception of the layout (Appendix 19, 127-132). The intention was that it made navigation easier and more intuitive as our intention was never to make it difficult to navigate—that was what the enemies were for—instead we wanted to explore and understand how people navigate a game using primarily audio cues for guidance.

This section of the methodology chapter details the research methodology of the thesis. First is the research strategy and method, then method approach and method of data collection, next the selection of sample and recruitment of participants, details about the research process and the type of data analysis, ending with a summary about ethical considerations and the research limitations of the project.

Research strategy

This thesis is based on conducting a pilot study and ultimately defined as a “small study to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study” (Hassan, Schattner, & Mazza, 2006, p. 70). During a research project a pilot study is one of the more important stages as it is conducted with the purpose to identify potential problem areas and deficiencies in the research instruments. In addition, it serves as a protocol done prior to implementation of a full study (Hassan, Schattner, & Mazza, 2006). Furthermore, members of a group that is conducting a pilot study have the benefit of becoming familiar with procedures in the protocol (i.e., before the large study), and consequently help the group decide amongst competing study research methods.

The main reason for conducting a pilot study on how audio cues engage and help players within an audio-based computer game was to conduct a small scale research study before embarking on a larger study. Ultimately the study can be sectioned into four parts according Hassan, Schattner and Mazza (2006): (1) we needed to determine the feasibility of the study—time taken to explain the research project and obtain the consent from the participants; the study procedures for data collection that had some initial problems in regards to structure and clarity of questions—; (2) the recruitment of subjects—the participants that were contacted and invited all agreed to participate in the study; (3) testing the chosen instrument for measurement (i.e., method and approach of data collection)—in the first test the seven participants took on average of 0:07:53 minutes to either complete or

forfeit playing the game. The amount of time spent on completing the interview section would fluctuate from 5 to 15 minutes sometimes more. While all attempted to respond to all questions, there were some that they missed. This appeared to be due to the broadness of the question. For example, “how many hours do you play a week?” (Appendix 5, pp. 18-64) resulting in some of the participants to forgo or answer outside the provided options. For some of the questions they were too vague which made it difficult for the facilitator and interviewer during a session as they had to provide further inquiries in the moment that should have been part of the prepared guide. Therefore, reformatting was done to overcome this problem in the second test. However, it came to pass that after the second test there were still some items in the interview guide which would benefit from another revision; (4) the final stage of the pilot study encompasses data entry and analysis—our findings showed that out of the nine subjects, eight were from Denmark and one from the United States. Findings are presented in depth in the analysis chapter. The minor difficulty that was encountered in conducting the analysis was because of the missing responses from some of the participants about the amount of time spent playing video games.

Research method

We used a mixed-method approach in order to better understand the objectives of the thesis. This means we relied on both qualitative and quantitative approaches for gathering data due to their respective advantages and purposes to achieve the objective. Our aim was to understand and explore how users perceive and apply audio cues to navigate a virtual world in the conceptual audio-based computer game we have developed.

Mixed-methods

Mixed-methods research designs involve research studies that utilize both qualitative and quantitative research methodologies to satisfy the proposed objective and purpose of the research question (Lavrakas, 2008). Thereby, mixed research methods combine the deductive and inductive inquiries of the scientific research methodology as well as use a variety of data collection and analysis approaches. The qualitative and quantitative methods can be conducted simultaneously or sequentially to satisfy the objective of the research question or possible questions. However, it provides a more comprehensive and detailed image of the research problem that is under investigation that would be either one of the designs—qualitative or quantitative—by itself. Furthermore, this research design approach can be classified into three types:

- In the exploratory mixed-method design approach, the researcher: “(...) conceptualizes a qualitative research study (...) collects and analyzes the qualitative data (...) uses the findings from the qualitative data analysis to conceptualize a quantitative research study. Finally, the researcher collects and analyzes the quantitative data to validate the qualitative findings” (Lavrakas, 2008, p. 10).

- In the explanatory mixed-method design approach the researcher: “(...) conceptualizes a quantitative research study (...) collects and analyzes the quantitative data (...) conceptualizes a qualitative research study. Finally, the researcher collects and analyzes the collected qualitative data to clarify and enhance the quantitative research findings” (Lavrakas, 2008, p. 11).

- In the triangulation mixed-method design approach the researcher “(...) simultaneously conceptualizes quantitative and qualitative research studies (...) simultaneously collects and analyzes both quantitative and qualitative data. Finally, the researcher uses the results from the quantitative and qualitative studies to validate findings from both studies” (Lavrakas, 2008, p. 11).

Qualitative versus quantitative research

The main characteristic of qualitative research is that it generally is appropriate to apply for a smaller sample size, while the outcome is not measurable and quantifiable (Radu, 2019). Its advantage over quantitative research is that it offers to better gain an understanding of underlying reasons and motivations (i.e., concerned with understanding and words). Thereby, to uncover prevalent trends in thought and opinion. Unlike quantitative research that is generally applied to a larger number of cases representing the population of interest. Its objective and purpose is to quantify data and generalize findings from a sample to the population of interest (i.e., concerned with measurement and numbers). Additionally, quantitative research is sometimes followed by qualitative research, which is then used to explore and investigate findings further.

Features of qualitative and quantitative research

Short summarization of the differences in features between the two research methods. For example, the aim in qualitative research is complete with detailed description. Whereas the aim in quantitative research is to classify features such as count them and construct statistical models with the purpose of explaining what has been observed. Another example is what we as researchers may or may not know in advance. In qualitative research the researchers may only know what they are looking for, whereas in quantitative researchers know in advance what they are looking (Langkos, 2014; Lavrakas, 2008). In qualitative research is applied during the earlier phases of research projects, and quantitative research during latter phases. In relation to the design of research projects it generally emerges as the study unfolds, whereas, in quantitative research all aspects of the study are carefully designed before data is collected. The data collection and approach are qualitatively reliant on the research as the data gathering instrument. In quantitative research the research instead uses tools such as surveys, questionnaires or equipment to collect numerical data that can be calculated. Often the data gathered in qualitative research is in the form of words, pictures or objects, however, in quantitative it takes the form of numbers and statistics.

Furthermore, a main characteristic of the two research methods is that qualitative research is focused on the subjective. Meaning, individuals' interpretation of events is of importance (e.g., uses participant observation, in-depth interviews, etc.). However, quantitative research is focused on the objective as it seeks precise measurement and analysis of target concepts (e.g., uses surveys, questionnaires, interviews, etc.). Lastly, qualitative data is generally ‘richer’ at the cost of being time consuming, and less likely to be generalized. Quantitative data has the advantage of being more efficient as it can test hypotheses, however, may miss contextual detail. Researchers are more likely to become more subjectively immersed in the subject matter compared to quantitative where they tend to remain objectively. Keeping separated from the subject matter (Langkos, 2014; Bryman, 2016, Lavrakas, 2008).

Research approach

The research approach utilized was a combination of both inductive and deductive reasoning. Inductive reasoning aims at developing a theory (i.e., moves from specific observation to broad generalizations), whereas deductive reasoning aims at testing an existing theory (i.e., moves from broad generalizations to specific observations). Our

reasons for utilizing the inductive approach were due to it considering the context where the research is active. In addition, it is ultimately appropriate for small sample sizes that produce qualitative data. However, its weakness is that it produces generalized theories and conclusions based on a small number of observations. Resulting in the reliability of research results being questionable (Langkos, 2014).

Method of data collection

For the purposes of this study semi-structured interviews were used as well as questionnaires. These interviews were separated into two stages. The first stage included demographic questions and was to be introduced before the second stage where the participants would play the game. The demographic questions were focused on gathering quantitative information such as age, gender, and time spent playing computer games as well as preferences hereof. The advantage of interviews was that they involve direct (e.g., both offline and online) contact and communication between the interviewer and the interviewee. Additionally, the questionnaire section aids in eliminating non-response rates as the interviewer can inquire further or help expand on a question. Resulting in none or fewer questions going unanswered. However, interviewers must have developed the required/necessary skills to successfully carry an interview (Bryman, 2016; Lavrakas, 2008).

Our reasoning for utilizing semi-structured interviews was that it offers flexibility in terms of the flow of the interview as well accommodates for the interviewer to include follow up questions and/or supplement the interview with relevant questions.

Disadvantages of semi-structured interviews is that they are time-consuming, labor intensive, and require interviewer sophistication (Adams, 2015). Ultimately the interviewer needs to have the skill and experience to be smart, sensitive, poised, and nimble as well as knowledgeable about the relevant substantive issues. The process of preparing for the interviews, setting up the interviews, conducting the interviews, and analyzing them is generally not as fast paced or easy as you would expect and think. Considerable time and effort should be expended and preplanned in the research process. As semi-structured interviews ultimately entail the arduous task of analyzing a vast volume of notes (e.g., fieldnotes and observations) and possible hours of transcriptions (Adams, 2015).

However, an advantage of using semi-structured interviews is that sampling from a smaller group would be more efficient than conducting large scale interviews. William Adams (2015) presents a list of considerations for employing semi-structured interviews for certain situations. Firstly, in general:

> “If you need to ask probing, open-ended questions and want to know theindependent thoughts of each individual in a groupIf you need to ask probing, open-ended questions on topics that yourrespondents might not be candid about if sitting with peers in a focus groupIf you need to conduct a formative program evaluation and want one-on-oneinterviews with key program managers, staff, and front-line service providersIf you are examining uncharted territory with unknown but potentialmomentous issues and your interviewers need maximum latitude to spotuseful leads and pursue them” (Adams, 2015, p. 494).

During our interview sessions we preplanned for scenarios related to all four, however, especially the fourth statement as it is often in this space where new information surfaces. Adams (2015) specifies further that within mixed-methods research, semi-structured interviews can be useful as an addition to supplement and add depth to other approaches. For example,

“If you need to conduct some in-depth reconnaissance before designing alarge-scale survey, configuring a focus group agenda, or constructing anoverall research strategyIf, after drafting a standardized survey questionnaire, you discover thatimportant questions cannot be effectively addressed without more open-ended questions and extended probingIf you want to explore “puzzles” that emerge (or remain) after you haveanalyzed survey or even focus group findings” (Adams, 2015, p. 494).

The people that may be appropriate for the semi-structured interviews can run the complete scope of those who are involved in the program being evaluated.

Designing and conducting semi-structured interviews

Practical steps for designing and conducting semi-structured interviews include selecting and recruiting respondents, drafting the questions and interview guide, techniques for this type of interviewing, and analyzing the information gathered (Adams, 2015).

When in the process of selecting respondents and arranging interviews for the semi-structured interview method, it includes a few basic elements. First having identified at the outset the target group, or groups, for semi-structured interviews, how do we as researchers then select respondents from among the target group? (Adams, 2015). As we are dealing with a smaller sample group and need to be aware of resource permits, it may or may not be possible to interview virtually everyone, such as all intended target groups (i.e., fully blind and visually impaired people). Even if time and resources hinder conducting a larger number of interviews, it is still relevant to get the perspectives of more than a few people.

Drafting questions and the interview guide

According to Adams (2015) questionnaire is not a recommended terminology for the compilation of semi-structured interviews, as the word connotes a "(...) fixed instrument to be read verbatim" (p. 496). Instead, of the flexible, interactive approach of semi-structured interviews. Rather, the interviewer must create the agenda for the interview guide, the outline of planned topics, and questions to be addressed, arrayed in their tentative order (Adams, 2015). We produced one interview guide that would be reviewed and edited according to the feedback or realizations accumulated during interviews. However, if semi-structured interviews are to be conducted with different groups, then Adams (2015) exclaims that it is necessary to create a tailored guide to each group. As we were dealing with a small group of people a single guide was adequate and fulfilled the purpose. The first draft of the interview guide was created during the last sprint of the first playable prototype. At the outset, we made sure to allot sufficient time—about two days while pretesting the game—to thoroughly draft, edit, pretest, and polish the interview questions and guide. For the purpose of conceding time for iterations and feedback from the group.

Additionally, it was necessary, and of importance, not only to avoid cramming an excessive number of issues into the agenda, but also to limit the list of potential topics so as to not make it longer than absolutely needed. As a result, we decided collectively in advance which of the questions were imperative for the investigation, as well as which ones were optional or ultimately unnecessary.

The refinement of the interview guide and its questions focused on how they were formulated, and/or the broadness, range, openness, and how the data can be processed, etc.

Once the required questions were selected, sorted by priorities, we would mark those with bullet points and underscore and bold font. The interview guide did not include second tier questions as we intended for the interview to be fully completed at each session. Any supplementary questions are welcome; however, they were to be added by the respective interviewer to their copy of the guide for the individual respondent. Thereby, clearly indicating a change in executive procedures. At the end of each test session a participant would have their own guide which had been filled out by the interviewer—not in the presence of the respondent. Resulting in the guide becoming a form containing the utmost important details relevant for the individual respondent.

We included several close-ended questions to firstly streamline the summary analysis and have solid quantitative points of reference (e.g., “were you able to defeat any enemies?”). Additionally, we were aware that as close-ended questions aided in streamlining the data collection, shortening the time spent completing the interview, that they were also ideal for open-ended probing. For example, “were you able to tell the layout of the whole level?” Which was followed up by asking, ”If so, do you think you could draw it?”. Besides being aware of the outset, the priority of questioning, the close/open-ended questions, there is also a need to prepare for the possibility that respondents do not speak English. It should be noted that the group was comfortable and proficient in communicating using the English language. Including that we may speak two different versions such as academic and common. Often miscommunication can happen due to group members not sharing the same cultural understanding of knowledge in regards to vocabulary, acronyms, and lingo.

For this purpose, we have designed the semi-structured interview and guide to accommodate everyday words of the target group, while making sure not to belittle them by talking down. Adams (2015) suggests that it would be useful to adjust question wording after the first round of interviewing. For example, we had in an earlier version of the guide phrasex the question: “what do you use the most, controller or keyboard and mouse?” which we later changed to “what type of controls do you use?”. Furthermore, we came to realize we had overlooked and omitted to include smartphones and tablets (i.e., devices that use touchscreen to navigate the system) as possible answers to the questions. Meaning, that if an individual participant primarily played video games on their phone and/or tablet, then they would presumably not have answered the close-ended questions with much thought. Due to these being geared toward either choosing the computer (e.g., laptop, desktop, Mac, etc.) or console (e.g., PlayStation, Xbox, Nintendo Switch), as an answer.

Another awareness is whether the question may evoke pressure to give socially acceptable answers (Adams, 2015). Resulting in the participant’s experiencing worry that their eligibility

could be at risk. For instance, two participants answered that they did not play video games due to them thinking that mobile games or tablets were not included as video games. This might be due to the large contrast between what a video game made for computer and mobile encompasses. One of them expressed that they thought the question hinted at a choice between computer or console. Once the confusion was cleared both participants answered “yes”, and each proved to play between 9 to 12 and 13+ hours a week.

Lastly, the agenda for a semi-structured interview should never not be interchangeable. For instance, if a conversation unexpectedly turns from the first to the sixth topic, it is expected that interview is adroit at reordering the topics in the moment and steer the conversation either back onto the skipped questions thereafter or return to them later. For this purpose, we attempted to anticipate the sequence of the questions based on whether it disrupts the flow or makes the conversation flow naturally.

For example, here’s a short version of the interview agenda:

- Customary pleasantries
- Introduce the participant for how the session will be conducted, what the main objective will be, and always make sure to get their consent for recording the session and having properly informed them what, why, and how the information will be used.
- Conducted the first part of the interview: demographics, which is to be done before the gameplay can proceed.
- Gameplay can begin once the participant has settled in, adjusted the volume to their liking, and is aware of how to control the player.
- Interviewer will start the recording of the gameplay while simultaneously capturing the talk-aloud section. Very little was uttered during the gameplay as participants were focused on the sounds.
- Gameplay can be ended in different ways depending on the participants need: (a) the participant completed the object and finds the key, (b) they forfeit by own suggestion, (c) the interviewer will suggest after a certain amount of time (30 minutes) agreed by the team beforehand—unbeknownst to the player—to offer the player the opportunity to forfeit and quit thereby not completing the game. If an option is correlated to not achieving the objective the interviewer is to appease the participant’s possible onset of inadequacy to complete the game. Making it clear that their efforts are still of use and much appreciated.
- After gameplay the interview section is conducted. Here the interviewer follows the presented guide and encourages the participants to talk freely about their experiences as well as suggestions they might have.

Sample selection

Convenience sample

We reached out to the participants using convenience sampling. We were mindful of trying to find people with possible visibility or hearing impairment. A convenience sample is taken from a nearby population such as a group of people that are easy to contact or reach. The only criteria for this method of sampling is that people be available and willing to participate. Additionally, this method of sampling is often not recommended due to its probability of sampling error (i.e., an error caused by observing a sample instead of the whole population) and general lack of representation of population. Nevertheless, it has its advantages depending on the contextual setting (e.g., convenience sampling can be the only available option for gathering data).

For instance, we have previously experienced that the influx that comes with corona often can result in day-to-day changes that may limit the availability of test people. During our last thesis we had to cancel a cooperation with a company which our study was based around due to a mutual agreement that future work effectiveness could be compromised, or time constrained as all parts were to uproot the daily structure.

Convenience sampling has various advantages including it being very fast, easy, readily, availability, and cost effectiveness, making it an attractive method approach for gathering data (Bryman, 2016). Firstly, the data collection is vastly expedited which is sought after when time is of the essence. This was the case for our study as we wanted to complete at least two test sessions, so we had enough data gathered to properly analyse. Secondly, as our study was a pilot test, we gained the advantage from its ease of research. However, this means we are aware of and not looking for an accurate sampling, instead collect as much information and move on to other aspects of the study. For instance, this was done by ultimately creating a questionnaire—a research instrument often consisting of a series of questions for the purpose of gathering data from respondents—and was included in the introduction section of the interview for our target audience. Overall, allowing for ease of research and focus on analysing the data instead of carefully selecting participants. Thirdly, a major advantage of convenience sampling is its ready availability due to it being collected with the population at hand and nearby environment. This allowed us to do multiple test sessions in an expeditious fashion where the first test sessions of the prototype were held

between the 27th of April and 2nd of May (6 days) and the second test session was done in the time frame of 4th of May and 9th of May (6 days). Lastly, a major aspect of convenience sampling is its cost effectiveness. This method makes it possible to allocate funds, or in our case time, to other aspects of the project. For example, we wanted to approach the findings from the first test session (i.e., prototype build version 0.5) and apply any necessary changes in the second test version (i.e., prototype build version 0.8) as fast as possible with the intention of quickly accumulating enough data to instigate the analysis phase.

However, convenience sampling also has its disadvantage, mainly bias (i.e., the findings of the sampling cannot be generalized to the target audience) due to bias of the sampling technique like under-representation of subgroups measured against the general population of interest (Bryman, 2016). Meaning, the bias of the sample cannot be measured and is why all conclusions based on convenience sampling should only be made about the sample itself. Secondly, this type of sampling is characterized with its limitations, or complete lack of power, to identify differences of population subgroups.

Participant sample

Approaches may vary depending on which type of group is interviewed. For this study we relied on convenience sampling. Ideally, if possible, the respondents should be chosen randomly to eliminate the biasing effect of convenience samples. As mentioned previously a convenience sample is a type of non-probability sampling that involves the use of a small portion of the population who is easily accessible.

Disadvantages of convenience sampling is the possibility of sampling error and lack of representation of population (i.e., collected samples may not represent the population of interest and therefore a source of bias). However, despite it not generally recommended for research, it can be effective in certain cases. The advantages of convenience sampling are that it can be utilized by nearly anyone and have been well documented. In addition, it is one of the more used as it is very fast, simple to use, readily available, and cost effective.

For instance, this type of sampling is useful for pilot testing especially when a project is under time constraints and quickly gathers data in order to gain an understanding of a certain topic: “how do certain audio cues engage and guide players within an audio-based computer game with limited graphics?”.

Respondents should rightfully have been identified and appointments set up before interviewers arrive at the site or initiate the call online. For this study we communicated with those chosen to request and schedule each individual appointment. This included a short introduction in advance to the experiment, noting the importance of the individual's responses and citing the project's relevance done by the respective group member who found the respondent. Possibly resulting in legitimacy and save time that would have been spent explaining or justifying the research. This only refers to what the research is about, how the data will be handled and where it might be posted. Introduction to the game itself and the experiments were done as part of the interview and testing sessions.

Prospective respondents usually ask how much of their time will be covered. To grasp how much time was needed we conducted pretesting, which yielded a rough estimate of how much time was needed to be allotted for each section in the test session. Based on this estimate, we would mention to the respondents during the recruiting that "it should not take more than 30 minutes or less". If the session dragged out more than anticipated, then the interviewer should ask permission for "would you be willing to answer just a few more questions" to at the bare minimum complete the core questions and thereafter the second tier of topics (i.e., freeform questions from the interviewer).

The time of day the session is held may have its advantages or disadvantages for instance a late afternoon session may benefit from not running up against another meeting. Nevertheless, as the time and place are necessary reflections to consider, it is not the primary concern—besides a respondent consenting to be interviewed—is in fact the content of the interviews. As the development of appropriate and well-crafted interview guides is essential (Adams, 2015). Each group member would always ask the people that were contacted for possible participation when they would have time to partake in this study. Whereas, if the participant did not provide a date we would then suggest a couple of dates and a timeframe they could choose from.

ID	**G**	**A**	**B**	**E**	**I**	**C**	**D**	**H**	**F**
gender	m	f	f	m	f	f	m	m	f
age	22	23	24	24	25	29	30	42	54

The above table is sorted in order of the nine participants' ages from young to older.

Research process

Sessions were held during April and May of 2021 with the participants of the table mentioned above. The researchers would ask them to participate in the research after explaining the nature as well as the scope of the study. All the participants were willing to participate in the study and would participate as followed:

	Test Session 1: April-May									**Test session 2: May**								
ID	**A**	**B**	**C**	**D**	**E**	**F**	**G**			**A**	**B**	**C**	**D**		**F**	**G**	**H**	**I**
gender	f	f	f	m	m	f	m			f	f	f	m		f	m	m	f
age	23	24	29	30	24	54	22			23	24	29	30		54	22	42	25

Table shows all participants sorted by the test session in which they participated.

All respondents were willing to participate in the research and the interviews were conducted the same day—between April and May of 2021. The discussion took place either via an online platform (i.e., Discord) or at the home office of the facilitators and the interviews lasted approximately 5 to 15 minutes. The researcher would during the interviews mainly keep notes, if it felt appropriate, in order to aid the group to analyse the data collected. Important note is that respondents during the interview were free to express their views on topics that may not have been included in the guideline. Ultimately the conversations flowed naturally and there was good interaction between respondents and facilitators. This might have been strengthened by their only being one facilitator present and interviews were conducted with individual people at a time—never a group.

Analyzing and reporting semi-structured interviews

As there have been a few closed-ended questions (e.g., ”do you play video games?”) we are then able to draw inferences from the data. The data set would then be cited as descriptive

statistics—are coefficients presented as short descriptives that outline a given data set—represented by the recruited sample as a subset of the population. These data sets have been applied to a table sectioned into measures for central tendency—several players seeked out the enemies before attempting to locate the key, which was their only objective—which can be summarized by comparing the amount of enemies killed and if the player completed the objective or not. Although, the data cannot indicate if the player stumbled upon the enemy by chance or if they found them by their own ability. However, we can then begin looking into ways to consolidate the themes, categories, and codes found in the respondents answers and further supplement them with illustrative quotations.

For processing open-ended questions it depends on the time involved, the number of people interviewed, the chosen method for analysing the questions as well as the number of topics to be addressed (Adams, 2015). To summarize and systematically assess the semi-structured interviews of the nine participants will take time not including the quantifiable aspects of the study. Nonetheless, the group evaluated that using semi-structured interviews as measurement instruments for this study would produce a depth of understanding about how audio cues can help and guide players navigate in an audio-based computer game using limited amounts of graphical instructions. Therefore, in spite of the labour intensive workload accompanied using semi-structured interviews. It would ultimately be worth the effort in regards to possible insights and information gained combined with the quantifiable data using descriptive statistics.

Data analysis

This section outlines the choice of *content analysis* as the research method to assess the interviews of the nine participants in terms of their perceptions (e.g., spatial contextual awareness) of the audio-based game and how it uses audio cues to help players navigate in a virtual environment. As mentioned previously the two test sessions were conducted between April and May of 2021, and the group gathered a total of 15 responses—the first test of the prototype had seven participants (F: 4, M: 3) and the second test of the prototype had eight (F: 5, M: 3)—that could be used for analysis. The group used the results from the *quantitative*—the demographic section of the interview and the quantifiable data gathered from recordings—and *qualitative*—semi-structured interview, observations, notes, etc.—studies to validate findings from both studies.

We used coding as an approach to data analysis more generally as it is focused on elements such as “Open coding [which] is the process of breaking down, examining, comparing, conceptualizing and categorizing data” (Strauss and Corbin in Bryman, 2016, p. ###). It is this process of coding that produces concepts, which are later to be grouped and turned into categories. Using each event and situation related by the respondent that corresponded to the aim of the study was labelled with a code. These codes were then compared, and those with a similar content were grouped into categories that were labelled at a higher level of abstraction. For example, we gathered all the participants favorite three games and would in turn compare them in (1) Categorized each game the player’s chose into which platform they were played on—PC: 13; Mobile/Tablet: 6; PlayStation: 5; Nintendo Switch: 3—; (2) categorized each platform into which platform the user preferred to use; (3) Sub-categorized out of the consoles was split in to specific consoles preferred (i.e., PlayStation, Xbox, and Nintendo Switch).

Description of content analysis method

The content analysis used in this study was both *quantitative* which is focused on counting and measuring, and *qualitative* which is focused on interpreting and understanding. Commonality between these two methods is that they categorize or “code” words, themes, and concepts within the texts and then analyze the results (Bryman, 2016). Content analysis is ultimately used to deduct the purposes, messages, and effects of communication content.

For instance, quantitative content analysis was used to research the importance of audio cues to help navigate the player blindly through a virtual environment. We then analyzed the participants' overall time spent completing and/or forfeiting each game as well as noted the completion rate, time spent playing, and number of enemies defeated. Then *descriptive statistical analysis*—used to describe the basic feature of the data in the study by providing simple summaries about the sample and the measures—to find any differences over time or between the players.

In addition, content analysis was also used to make qualitative inferences by analysing the meaning and semantic relationship of words and concepts mainly of the interview transcriptions and facilitators observations and notes from the sessions. For example, to gain a better qualitative understanding of participants' engagement with the audio-based computer game, we would look for certain types of words or phrases such as “*feel”, “thought”, “seemed”, and “impression*”. As these types of words could connote their

individual perceived experience when met with items—this include all created elements, (game)objects, aspects and functions like programming created specifically for each build version—that worked as a sound emitter (i.e., audio that is generated to be received by a user). Mainly to better understand the meanings of these interrelations by identifying commonalities and what other words or phrases appear next to them such as "*loud", "fun", "unexpected", "interesting", and "scary*". Thereby, create a collective conception of the participant's internal imagery or depiction of the virtual environment.

However, due to the method of content analysis being applicable to wide range of texts as well as being used in variety of fields (e.g., cognitive science, psychology, marketing, media studies, and other social science disciplines) this approach has a diverse range of objectives:

- Find correlations and patterns in how concepts are communicated
- Understand the intentions of individuals, groups, or institutions
- Identifying information of a biased or misleading nature in communication
- Revealing differences in communication in different contexts
- Analysing the consequences of communication content like the flow of information (i.e., emitter and receiver) or audience responses

For this thesis our interest was first and foremost on the feasibility of the study, which was executed by conducting two smaller experiments designed to test and gather information—using measurement instruments (i.e., tools for data collection) from both quantitative and qualitative research methods—prior to conducting a larger study. To explore how certain audio cues engage and guide players within an audio-based computer game using limited graphics.

Ethical considerations

The study was subjugated to several possible ethical conflicts which were handled with as much care as possible. First it was of utmost importance that the participants were clearly informed and aware of the nature and scope of this research as they gave their consent and acceptance regarding their participation in the study, through verbal and signed consent included in the interview guide. This is the basic principle of showcasing a respect for autonomy and justice.

In regard to showcasing nonmaleficence (i.e., harm and its effects are considerations and part of the ethical decision-making process), all participants should be reassured that any identifying information remains anonymous and cannot be traced back to them. In addition, their participation is voluntary, and they were free to decline and opt out at any point and time in the study including having their data permanently removed from the record. As this is their human right. Beside this it was also important that the experiment had a flexible setup and avoided excluding certain types of hardware as well as software in regards to the technology—beside the game only being able to run on Windows computers. For instance, if a participant did not have Discord another platform would be provided to hold the session online or the facilitator could—if the respondent felt safe—come to their abode and set up the necessary equipment to conduct the test session.

Along the line of the principle of beneficence (i.e., an act of doing good or semblance of moral obligation) it was important within the group that there was an understanding and collective agreement on clear distribution of responsibilities for setting up, carrying out, monitoring, evaluating, adapting, and stopping the experiment. Especially due to all sessions being one-on-one.

Limitations of research project

It is not uncommon that a research study may encounter certain limitations due to constraints on either the research design or methodology. This section will detail the more important constraints that occurred or were noticed throughout the study.

Limitations to the study such as constraints often factor into the impact findings of the study. This is one of the reasons why transparency is a major priority when it comes to the validity and replicability of a study research, such as this pilot study, or feasibility study. However, discussing the limitations of the study may invoke a sense of undermining its research value or showcases potential weaknesses. Regardless, it is imperative that we identify problems met which in turn strengthens the study's validity, due to it being expressed by the researchers themselves and not external sources like the reader. Furthermore, identifying problems with our research informs the reader that we have reflected, evaluated, and considered the impact of research weakness through and through while yielding a depth of understanding of our chosen research topic.

The type of study limitations met was mainly a result from the methodology:

- We had some concerns in relation to issues with sample and selection as we used convenience sampling which is known for its sample bias and selection bias. As a result the participants in our sample do not reflect the general population.
- As this was a pilot study the sample size was deemed respectable. However, for more statistical measures, a third set of participants not part of the first two test sessions would have provided more opportunity to identify significant relationships from the data. Nonetheless, the size was appropriate for a pilot study, and if further study is conducted the addition of a third group would provide interesting data.
- Minor imperfections with how the guide was structured as how the questions were propositioned, which was used to collect the data. The guide would need reformatting and some questions need more clarification in relation to the topic. We realized this when going over the interviews together and noticing the supplemental questions added which greatly helped identify various codes. There were also answers left out despite being used to quantify the data.

To summarize this chapter outlined the process for gathering and analysing data, as well as the process for approaching the research question. In addition to describing the research method, we covered the reasons for choosing it, and why we thought it would produce the best results and findings.

Design

In order to observe and understand how players perceive sound and navigate through game levels using only hearing, a prototype of a functioning game was built with the intention of assessing the potential and possibilities of a system to guide players using audio only.

The following chapter presents the idea generation phase and design process leading towards a functioning prototype to playtest.

To observe how audio enables the enhancement of navigation in guiding players through game levels, playtesting of a diverse range of computer games across multiple genres were conducted. Consequently, the tests were produced to achieve inspiration for the game-prototype which was planned for user testing of navigation through audio.

Double Diamond design process

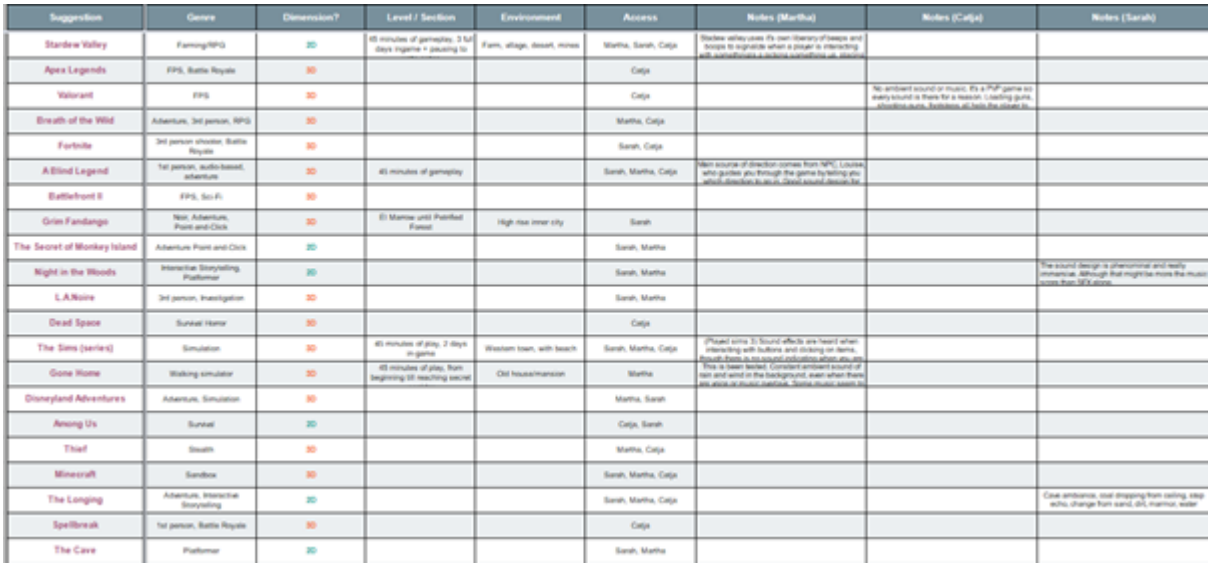
Since our focus has been on using audio-only to understand how audio cues could serve as a navigational tool to navigate players through a game world, we wanted to produce our own version of said game world. Therefore, we firstly gathered data from other games on how audio was used, wherein we adapted a *Double Diamond design* process of discovering, examining and then developing a prototype to be tested upon. The design process helps designers focus on what is being done and to be done in the process *(Design Council, 2015) The phases within the process appear fuzzy as nothing is ever certain and designers will continuously iterate upon the selected problem, resembling Rittel & We*bber (1973) framework for identifying and working with wicked problems in design:

“One cannot understand the problem without knowing about its context; one cannot meaningfully search for information without the orientation of a solution concept; one cannot first understand, then solve”. (Rittel and Webber, 1973, pp. 162)

Hence, the process becomes a continuous spiral of understanding and solving the problem, which will be explained further throughout the design process. Thus illustrating the process of iterating through various design ideas in order to produce a testable prototype.

Analytical play

The games selected were described throughout literature of the field as possessing creative sound design in regards to informing the players of the game world and their actions, such as Dead Space (Visceral Games, 2008), The Sims series (Maxis, 2000-) and Bioshock (2K games, 2007). These were found e.g. as recommendations in Karen Collins' *Game Sound* (2008) and Tim Summers' *Understanding Video Games Music* (2016). Furthermore, all members of the group are avid gamers and as such already possessed a large variety of games, which could be drawn upon to playtest. Contemporarily there exists numerous games and genres available, and so the group members agreed upon examining what games they each had available in their respective libraries. These games were selected from different genres as we examined how audio was contributing to informing the player and enhancing gameplay experience without specifying a genre. They were additionally observed on how audio contributed to player engagement, whether the sounds were noticeable and what effect they offered the narrative.



Suggestion	Genre	Dimension?	Level / Section	Environment	Access	Notes (Martha)	Notes (Cat)a)	Notes (Sarah)
Stardew Valley	Farming/RPG	2D	65 minutes of gameplay, 3 full days ingame + pausing to	Farm, village, desert, mines	Martha, Sarah, Catja	Stadew valley uses its own library of beeps and boops to signalize when a player is interacting		
Apex Legends	FPS, Battle Royale	3D			Catja			
Valorant	FPS	3D			Catja		No ambient sound or music. It's a PVP game so every sound is there for a reason. Loading guns, shooting guns, footsteps all help the player to	
Breath of the Wild	Adventure, 3rd person, RPG	3D			Martha, Catja			
Fortnite	3rd person shooter, Battle Royale	3D			Sarah, Catja			
A Blind Legend	1st person, audio-based, adventure	3D	45 minutes of gameplay		Sarah, Martha, Catja	Main source of direction comes from NPC, Louise, who guides you through the game by telling you which direction to go in. Good sound design for		
Battlefront II	FPS, Sci-Fi	3D						
Grim Fandango	Noir, Adventure, Point-and-Click	3D	El Marrow until Petrified Forest	High rise inner city	Sarah			
The Secret of Monkey Island	Adventure Point-and-Click	2D			Sarah, Martha			
Night in the Woods	Interactive Storytelling, Platformer	2D			Sarah, Martha			The sound design is phenominal and really immersive. Although that might be more the music score than SFX alone.
L.A.Noire	3rd person, Investigation	3D			Sarah, Martha			
Dead Space	Survival Horror	3D			Catja			
The Sims (series)	Simulation	3D	45 minutes of play, 2 days in game	Western town, with beach	Sarah, Martha, Catja	(Played sims 3) Sound effects are heard when interacting with buttons and clicking on items. Sounds there is no sound indicating when you are		
Gone Home	Walking simulator	3D	65 minutes of play, from beginning till reaching secret	Old house/mansion	Martha	This is been tested. Constant ambient sound of rain and wind in the background, even when there are voice or music overlays. Some music seem to		
Disneyland Adventures	Adventure, Simulation	3D			Martha, Sarah			
Among Us	Survival	2D			Catja, Sarah			
Thief	Stealth	3D			Martha, Catja			
Minecraft	Sandbox	3D			Sarah, Martha, Catja			
The Longing	Adventure, Interactive Storytelling	2D			Sarah, Martha, Catja			Cave ambiance, cool dropping from ceiling, slap echo, change from sand, dirt, marmor, water
Spellbreak	1st person, Battle Royale	3D			Catja			
The Cave	Platformer	2D			Sarah, Martha			

Figure 4. Table of suggested games to play through in accordance with availability and relevance.

The games were placed in a table as seen in figure 4. A game was placed in the column suggestion, where notes on the genre and dimension, referring whether the game was of 3D or 2D space as this too impacted the navigation on screen, were added to help categorize the games. This was further added to observe a pattern in how sound and space consisted between the game genres.

An imbalance of dimensions and genres is presented as more 3D games than 2D were added. Furthermore, not all games on the tables were tested, both due to time constraints as the testing of the games took significantly longer than planned, and due to availability of the games. For example, the investigation game *L.A. Noire* (Rockstar Games, 2011) was planned for testing, however, due to issues with game availability, this was not made possible.

The column for level/section and environment was added in order to observe what type of environment the game or the level of the game was played through in order to observe whether a pattern would emerge of the type of sound effects played during comparable settings. Our continuous focus remained on sighted players, and therefore the games added to the tables consisted mainly of mainstream games targeted towards gamers without visual impairment, albeit *A Blind Legend* (Dowino, 2015) was added due to its popularity and innovation regarding binaural 3D sounds. Moreover, the game is described as not only targeted towards users with visual impairment, but for players who seek an original, sensory experience and as such it too was added for playtesting.

From the list of selected games, each group member selected games they had available for playtesting. It became apparent early in the playtesting that group members selected games they were already familiar with in order to avoid distractions from the gameworld and new mechanics which the group members would have to spend time familiarizing themselves with before they could observe the sounds attached to the mechanics. The exception was the procedurally-generated survival game *Valheim* (Iron Gate Studio, 2021), which had only been available for playing about a week before the categorization and selection of games to playtest. The game was selected due to its rising popularity within the gaming community, an indication that it would turn into a mainstream game.

All games were tested on PC-computers with the exception of the island-simulator *Animal Crossing: New Horizons* (Nintendo, 2020) as it is exclusive on the Nintendo Switch platform. However, due to *Animal Crossing: New Horizons*' rising popularity consequently during the first-half of the Covid-19 outbreak, the game was chosen as well. The game was an interesting case to examine as the game had gained traction among blind gamers as well, as it was observed by an example of a blind YouTuber, who explained how they played the game using items to establish sound cues (Minor, 2020).

In order to examine the usages and role of the sounds within the games, it was recommended to lower the volume of music in-game or completely turn it off if possible due

to music oftentimes being used for atmospheric or narrative purposes, while the group was concerned with the usage of sound effects purely.

As mentioned in the inspiration chapter, in *Animal Crossing: New Horizons*, a function for lowering music is not presented, possibly due to the music's integration into the game itself as each hour of the day is assigned a different music piece while when talking to the non-playable characters, a sample of music is played depending on the type of personality and species the character possesses. However, most contemporary games provide options of volume sliders to separate sound effects from music, while some games further provide options for dividing the sounds by ambience, voices etc. As previously mentioned, in the farming-simulator *Stardew Valley* (ConcernedApe, 2016), volume sliders are presented for separating ambient sound, such as wind and bird chirping, from footsteps.

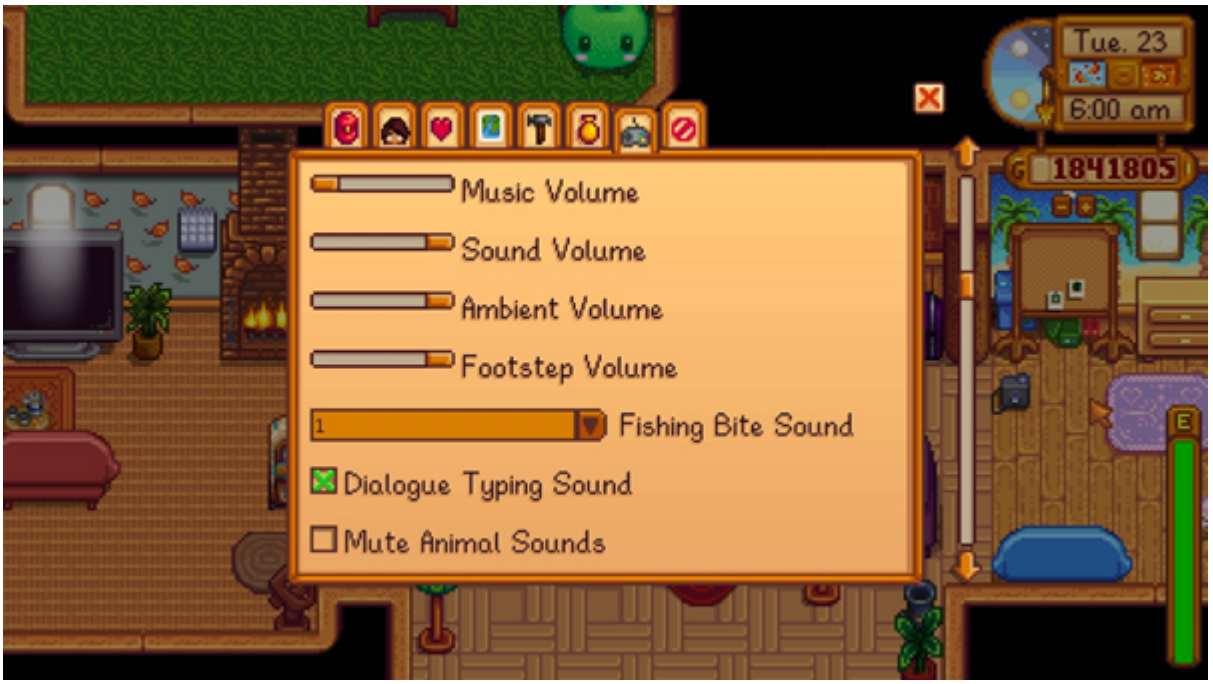


Figure 5 – the volume options presented within the farming-simulator, Stardew Valley (ConcernedApe, 2016).

While playing through the games, the method of analytical play was applied, wherein games are played with intent on listening to a variety of sound cues and noting how the sound outputs alter the gameplay experience (Summers, 2016). It encourages exploratory playtesting when interacting with the games, such as going in the opposite direction of the game's intent or performing tasks in areas where the task should not be performed e.g. in *Animal Crossing: New Horizons*, a sound signalling error is played when attempting to cast

the fishing rod in an area which does not contain a body of water, hence informing the player that their action cannot be performed. Therefore, the analytical play method aids in examining and understanding the relationship between game sound and gameplay experience.

When playing through the games, sound effects were written down in hand on a notebook whenever one occurred in-game. This required quick note-taking and oftentimes the game had to be paused if multiple sounds were played at once. Some sounds would be missed entirely as multiple were heard at the same time, although most games offered the opportunity to repeat the action which had initiated the sound effect, or by simply waiting for the sound to be played once more, such as bird chirping or the sound of thunder.

Another issue with the application of the method arose after the playtesting, where a lack of overview on the notes occurred. As most sounds occurred unexpectedly in the game, they were written down as a long list of keywords with no clear labelling which made the process of sorting and categorizing the notes afterwards difficult and drawn-out. Due to the problematic categorization, the sounds were merely looked at together and categorized depending on what function they served in the gameplay experience e.g. whether they were ambience, footsteps or sound effects occurring from the game interface such as inventory system.

Summers (2016) recommends that while performing the method, the play tester records their playthrough of the game to examine and compare the sounds across multiple playthroughs afterwards. Screen-recording along with the note-taking method are preferred methods to perform instead of real-time note-taking as the researcher can focus on playing through the game levels and assembling sound samples versus stopping the game in order to write down notes. However, by taking notes in real time, it gave the researcher an immediate overview of the sounds available in the game and thus encouraged further exploration of more sound samples. If the researcher has written notes depending on what was heard during a recording, there is a chance of occurrences where the researcher would have missed opportunities for sound cues e.g. when taking notes during *Animal Crossing: New Horizons*, the researcher realized that the inside of each public building has its own distinct sounds and so each public building was explored. While taking notes in real time, it additionally provides the researcher with a space to consider where else within the game world they need to explore in order to sample sounds.

Furthermore, Summers (2016) suggests that multiple playthroughs will be necessary for each game, as sound played during games can appear altered depending on the action or location, while there might also be occurrences of sound cues not being initiated due to errors or glitches which can alter a player's experience. As the selected games differed vastly from each other, no particular time frame was applied on how long each game should be tested for. For example, the walking-simulator *Gone Home (*Fullbright, 2013*)*, can be completed in less than an hour and all sounds can be found fairly early in the game. While in open-world adventure-games such as *Skyrim* (Bethesda, 2011) or *Valheim*, where each creature has its own distinct sound, it could take hours or longer to find and sample all the different sounds. This especially became apparent in *Valheim* as a procedurally-generated game, where each world generated varies and therefore it could take hours to find all the sound samples of the game.

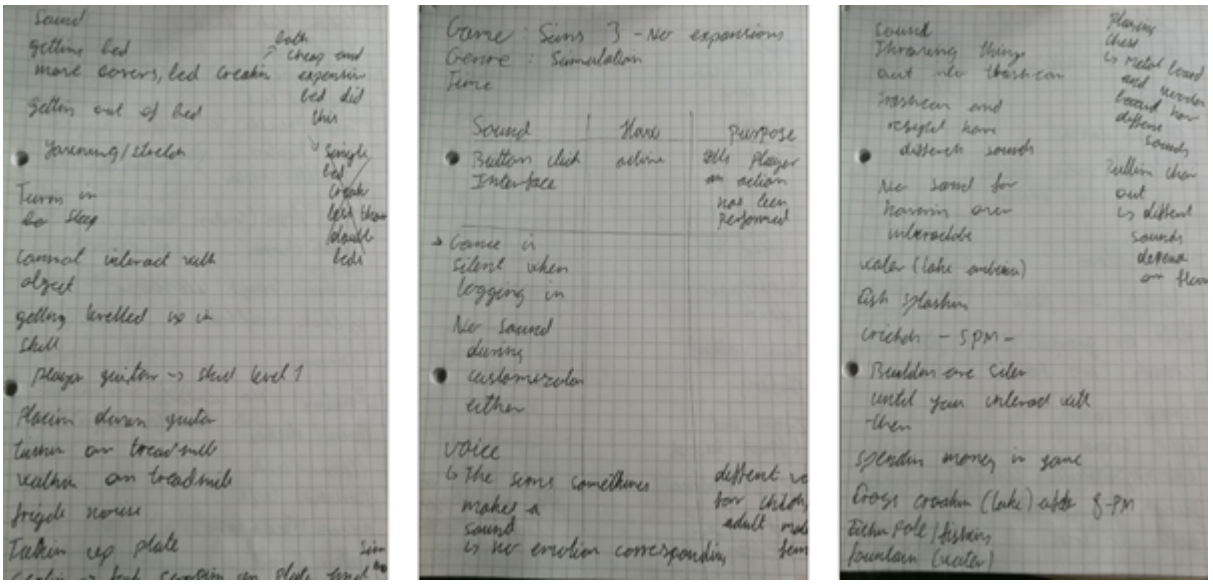


Figure 6. Examples of notes taken while playing through selected games.

Results

After selecting and examining a range of games on their usage of audio to both inform the player of the game world and navigate them throughout the game level, several patterns seemed to occur throughout the playtests. The most prominent patterns are listed as following:

- Footsteps varying depending on what material the player avatar walked upon was a common usages of sound throughout most games playtested. Common flooring sounds seemed to differ between wood, marble, stone, sand, grass, dirt and carpet. In the life-simulator, *The Sims 3* (Maxis, 2009) despite the game usually being played at a distance where the player controls the life of selected characters, when the camera is zoomed far enough in on an individual player character, their footsteps produce a sound which varies depending on what type of flooring they walk upon.

- A common pattern consisting across most of the selected games appears as constant ambient sound which persists across the entire game and provides a sense of depth to the game world. In *Gone Home*, a constant sound of rain with the occasional overlay sound of creaking wood from the old house or thunder from the outside aids the narrative of the storm outside. In the games *Animal Crossing: New Horizons* (Nintendo, 2020), *Skyrim* (Bethesda, 2011), and *Valheim(*Iron Gate Studio, 2021*)*, a constant wind is heard throughout the entire playthrough, occasionally layered by the sound of wind rustling leaves, bird chirping or buzzing from insects. Furthermore, when moving towards water, there will additionally be added a constant ambient sound of waves, the crashing of a waterfall or a river running.

- Games with a day and night cycle will have different sounds depending on what time of day it is. This is for example apparent in *The Sims 3*, where lakes and ponds will produce the sound of ambient water as well as fish occasionally splashing around during the day, while during the night will provide a constant croaking of frogs. In *Stardew Valley*, no ambient sound is provided during the morning hours, but around afternoon, the sound of wind will pick up and birds chirping will be layered upon, while evening and night-time provide a constant sound of wind followed by the sound of crickets and occasionally distant howling or barking layered upon.

- A common pattern occurring within most games is the interface consisting of one sound e.g. when clicking a button, opening and closing an inventory, the same tone will be played. In *Animal Crossing: New Horizons*, a few specific items will have a distinct sound when selected, such as the slingshot or fishing rod, while in *Skyrim*, each weapon makes a different sound when equipped e.g. the two-handed axe has a deeper sound played than when equipping the one-handed while each spell too will be different when equipped. None of the selected games made a sound when the mouse/camera was hovering over an object.

Sketching the first prototype

Based on the findings from playtesting the selected games for their usage of sound, we decided that a first-person shooter would provide an appropriate genre as a framework for constructing a game to navigate players using audio only. A consistent pattern within games is utilizing sound as feedback to actions, wherein the sounds either signal when actions have or can be performed or they are used to enhance empathy and engagement for the narrative (Huiberts S., 2010). However, an issue arises when developing an audio game where players e.g. will not know when the mouse cursor is hovering over an interactable object or if they are engaged in combat and their target is within their aim. Occasional games incorporate sounds to inform the player when their aim has encountered a target or when they themselves are targeted by enemies or other players. For example, *Borderlands 3* (Gearbox Software, 2019) incorporated a feature such as auto-aim where the aim of the selected weapon centred on the nearest target. Additionally, Apex Legends (Respawn Entertainment, 2019) has a character that will voice out loud when an enemy is aiming at her. Introducing a system of audio only, we decided that a first-person perspective would provide an engaging experience and a simple control scheme for the player to navigate through the game world.

Grimshaw M. (2007) states that player immersion is one of the goals of FPS games, as they present opportunities and possibilities for immersive sound design regarding use of sound-beacons, weapon-based sounds and squat-signalling sounds. The genre additionally offers opportunities for creating realistic soundscapes by adding reverberation depending on the type of material sound passes through as well as 3-dimensional sound environments (Grimshaw & Schott, 2007; Garner & Grimshaw, 2011; Gordon, 2007; Garner T., 2013). Observing how visually impaired gamers interact with game levels in FPS games such as *Call of Duty* we understood that using a FPS framework for the game in terms of combat, perspective and navigation was a variable possibility.

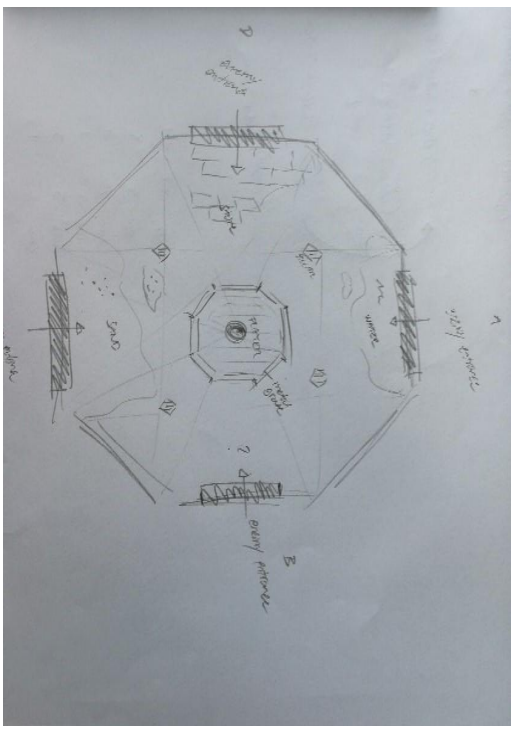
Huiberts S. (2010) states in a footnote:

“Concerning the perspective, the first person perspective is often considered as a very immersive perspective, because the player almost feels one with the avatar(...) opposed to for instance, the third person perspective, seeing the facial expression of the avatar is generally not possible in a first person perspective(unless the avatar is looking in a mirror) and this makes it more difficult for the player to know how the avatar ‘is feeling’, If course, in

this case, sound can be used to communicate the emotions of the avatar, in addition to the other modes of communication” (p. 100)

As such, a first-person perspective provides opportunities for realism by offering an immersive view of the world. As we decided on a solely audio-based game where the player did not need to see their character, it was not necessary to make them use a third-person character. FPS additionally offer players greater freedom in interacting with the game world as they are oftentimes allowed the control and movement to explore the game world independently, therefore creating the groundwork for a realistic auditory experience (Jäger & Hadjakos, 2017; Collins, 2008).

After selecting a game genre to serve as framework for the game design, a low-fidelity paper sketch was enacted in order to make our ideas visible and accessible for all group members. The initial idea was the game level consisting of a singular room with different types of flooring in each corner to serve as navigational aid for the player. Enemies would appear from different doors multiple at a time and the player would have to eliminate a specific amount of enemies to progress the game, while vending machines for upgrading weapons and acquiring health would be available. The game would be won once a specific amount of enemies had been eliminated.



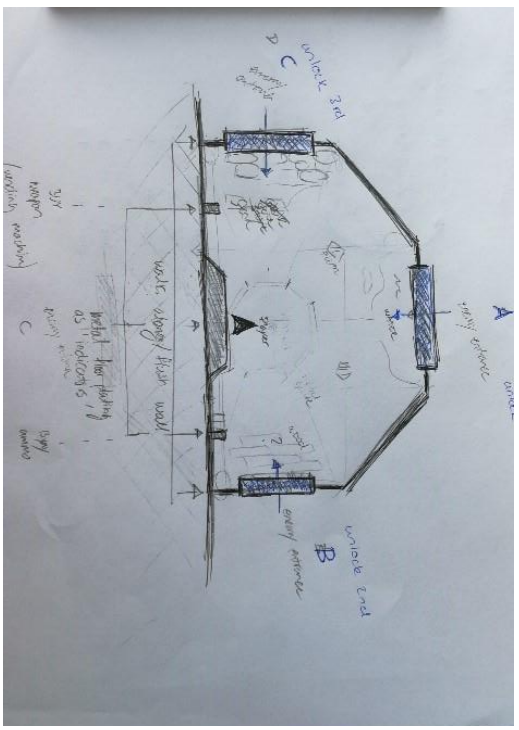


Figure 7. Sketches of the initial layout of the game level. The original design consisted of a singular room with various terrain sounds.

However, we expanded upon the initial idea by allowing the player the agency to move between different rooms and explore the game layout in order to observe how players engaged with a game providing navigation through audio cues. If the player persisted in a singular room and were to fight enemies in a survival-styled game, we feared a limited amount of sound could be expressed as well as making the game too easy as the player would merely be standing in the middle of the room and shooting towards the sound of enemies. Therefore, we needed to provide the player with a purpose of exploring the game level.

Core diagram model

Using Kim's (2012) model of core diagram, we evaluated the various game elements. The purpose of the model is aiding understanding and evaluation of a game vision from its core mechanic.

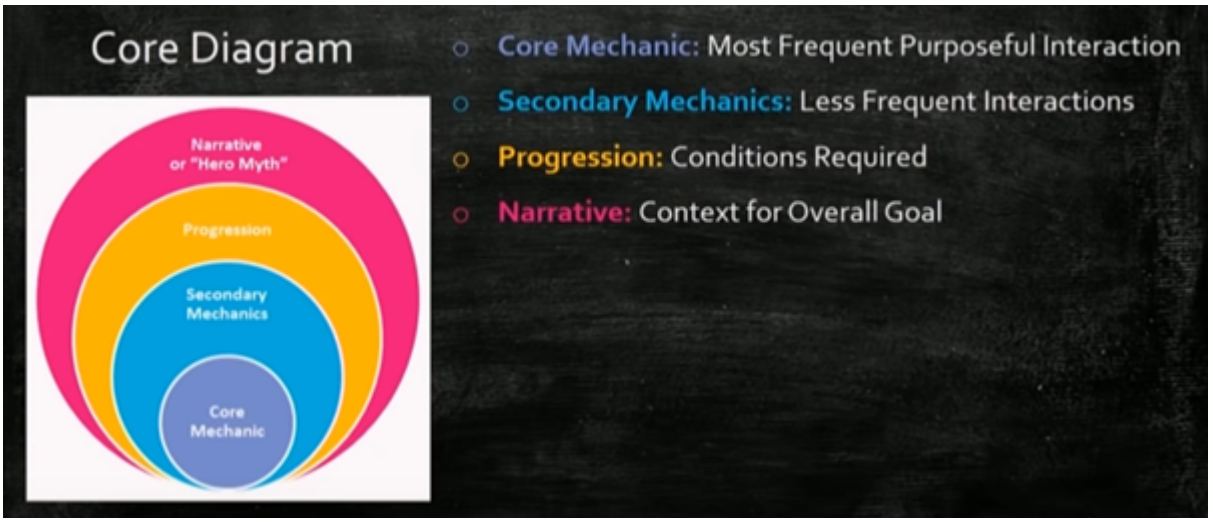


Figure 8. Core diagram model as presented by Barrett (2017)

Figure 9. Game elements of the prototype divided into the categories of the core diagram.

In the core diagram model, the core mechanic encapsulates the most purposeful interaction which happens during gameplay. As the planned game laid within the FPS genre, we planned the most purposeful interaction to be shooting. When presenting the core mechanic, Mark Barrett provides the example of Pac-man, wherein he specifies that movement works as the core mechanic due to it being the minimum viable interaction (Barrett, 2017). Similar suggestion applies to the planned prototype, where the player must move the player avatar in order to progress within the game. However, a core mechanic must additionally attach a strong meaning to its interaction and thereby create an unique experience for the game, or else most action-based games would present movement as their core mechanic (Kim, 2012). Hence shooting is set as the core game mechanic as the player must have means of defending themselves in the game.

The secondary mechanic is a less frequent mechanic, oftentimes layered on top of the core mechanic. Here, we presented the enemies themselves as a mechanic as they serve as obstacles instead of the end goal for the player, and thereby giving the player the ability to run away from a fight if it proved to be too difficult for them to find and eliminate the enemies.

The progression of the game is the condition in which the state of the game changes e.g. an update in a quest log or an ability to power up the player. A new goal of the game was created wherein the player's objective was to locate a key in order to win the game and said progression then occurred when the player picked up the key and hence changed the state of the game from finding the key to winning the game.

The narrative places the inner layers of the core diagram into a collective theme and context of the game world. For the planned game, in order to provide the player with a narrative context of the game environment, we decided to present the idea of an experiment gone wrong and thereby monsters were running loose within the game level. Taking inspiration from older FPS games within the genre with the idea of otherworldly creatures serving as cannon fodder, the monsters would provide the player with immediate connotations of how they could interact with the other creatures in the game level.

To accommodate an exploration-type game, multiple rooms were planned. The concept and details of the game became a bit more complex, and thus *The Sims 4* was used to create the layout of the game as it provides a set of architectural tools. Using *The Sims 4 (Maxis, 2014)* for mapping out the game level allowed the group to visualize the layout of the game and iterate the size and structure of the game world.

The game level then consisted of a centre hub taken from the first paper sketch where the player would start. The hub would lead into two separate rooms which both would be connected with a third room at the top.

In order to provide a challenge for players and optimize later testing, the key would spawn between a variety of different locations. Enemies would be stationed around in the rooms for the player to either avoid or eliminate, though it was possible to win the game without interacting with them at all.

Friberg and Gärdenfors (2004) define audio games as "(...) games that feature complete auditory interfaces, so they can be played without the use of graphics" (p. 148). Therefore, we knew all gameplay elements needed to contain a recognizable sound as no visuals were to be presented, while the mechanics and layout was simplified from the start to allow room for further improvement and reduce playtester frustration.

Figure 10. An initial layout of the game based on the first sketches. The expansion included two additional rooms to produce different terrain sound.

Figure 11 - an iterated version of game layout. A third room was added as an outdoor area, wherein the player would experience nature sounds.

Overview of the game

Once a comprehensive architectural mapping of the game layout was agreed upon, the prototype was developed in Unity version 2020.30f1. The purpose of the initial prototype regarded observing how player's navigated a simplified game level by relying on hearing only, while a limited amount of sounds was played during gameplay, meaning that enemies only produced a singular sound regarding footsteps and the tasks the player needed to complete was narrowed to one objective. We speculated the approach would be variable and sustainable in iterating improved prototypes by increasing the complexity of game functionality and features based on results gathered from the playtests.

Sound

While evaluating game elements and mechanics implemented to the prototype, considerations regarding the sound design in game and how to obtain accurate and representative sound clips were conducted. Although the premise of the prototype was simplified to add additional iterations in later evaluations, the game would have little to no visuals to represent objects in the game level and as such, it was important to find sound that the player would understand from the first moment they opened the game.

Due to the effect of realistic sound clips with a deep amount of details, the foley sounds were considered. The technique enables the creation of original sounds with the combination and representation with visual objects in unexpected ways e.g. rain sprinkled on paper used as sound to represent rain (Sonnenschein, 2001; Morimoto, Kojima, & Usami, 2017). By using original sound clips produced by the project group, we could ensure the sounds would be representative and realistic, or hyper-realistic which could advance the player's cognitive perception of the game world according to the desired presentation. For example, hammering into a watermelon and recording the wet impact to use as a sound for when a bullet hits an enemy.

However, due to lack of time as the prototype was first constructed later in the project process, there was little to no time to research techniques to record and polish the sound files. Foley artists usually produce sounds in foley rooms with an array of item combinations to produce the desired sounds (Sonnenschein, 2001). However, the project group did not have the resources, technology or time to locate or create a foley room of our own for recording of sounds. Furthermore, as it was early on established that the game would be

within the FPS genre with the use of guns as a key element of the gameplay, we were unsure what sounds to use in order to produce a sound similar to a shotgun.

Therefore, rather than recording and editing a library of original sounds, we decided to procure pre-existing sound files available from the below mentioned Unity FPS Microgame template as well as through the website freesound.org, wherein singular sound clips produced by other creators can be acquired. The sound library provided time and access to a variety of sound clips the project members could choose between in order to select the representing sound. Hence, the UI interface sounds for starting the game, hovering over interactable object as well as the sound for winning the game were selected from the website with the criteria that they needed to be recognizable and understandable for the participant while the sound clips needed to be no more than a singular second long to prevent the sound from overlapping.

While evaluating sound clips for footsteps to signal the player's movement in the game level as well as notify the player of the location of nearby enemies, it was decided to record our own footstep sound from the game The Longing (Studio Seufz, 2019). The decision arose from a lack of footsteps appealing to the project members as signalling that the player was indoors, while the Longing provided singular sound footsteps with a distinct sound of impact on ground. Therefore, this was recorded in the game and edited down to a singular tone so it could be used for whenever the player was pressing any of the movement keys. The sound was added to the enemies thereby avoiding confusion from the player if the enemies produced different sounding footsteps.

Room layout

Unity's Microgame Template was downloaded as it permits developers customization and iteration of game levels through a range of features such as a player character with implemented functionality such as jumping and running and a weapon system. Implementation of the template allowed constructing the game level and instantaneously reviewing the scale and space of the rooms. With four rooms in total constructed, each room aimed for the player character to manoeuvre from one end to the other in approximately five seconds by holding down any of the standard WASD keys, hence ensuring the player would quickly encounter an obstruction regarding a wall and then change their direction. We speculated that if the rooms were too small, players would feel constrictive and frustrated while the difficulty of finding the key object would decrease. However, if the room layout

dissimilarly appeared too spacious, players would experience frustration from navigating in one direction for too long with no other feedback, while the difficulty of encountering the key object and enemies would increase. We wanted to ensure that the level that the players remained in a state of flow by allowing uncomplicated mechanics and game level structure which would be easy to master as we presumed the lack of visual graphics informing the player of their location would appear challenging enough (Csikszentmihalyi, 2008).

Doors connecting the rooms included a sound of the door opening and closing as soon as the player entered a trigger box which registered the collision. The door gameobject would then be disabled for the player to pass through and into the next room and then enabled once the player exited the trigger box. The purpose of the door was to supplement a level of complexity to the navigation, as players would navigate between different rooms and thus opportunities to observe whether players would react to the sound of a sliding door could enable further understanding of the player's navigation. The sound of a door is produced as a 2D sound, wherein it appears with no effect on distance or direction of the player. While the player character was walking on the ground, a sound of footsteps was produced. When the player character encountered a wall, the footsteps were altered in pitch and volume to appear several tones deeper, subsequently enabling the player to observe that they had encountered an obstacle.

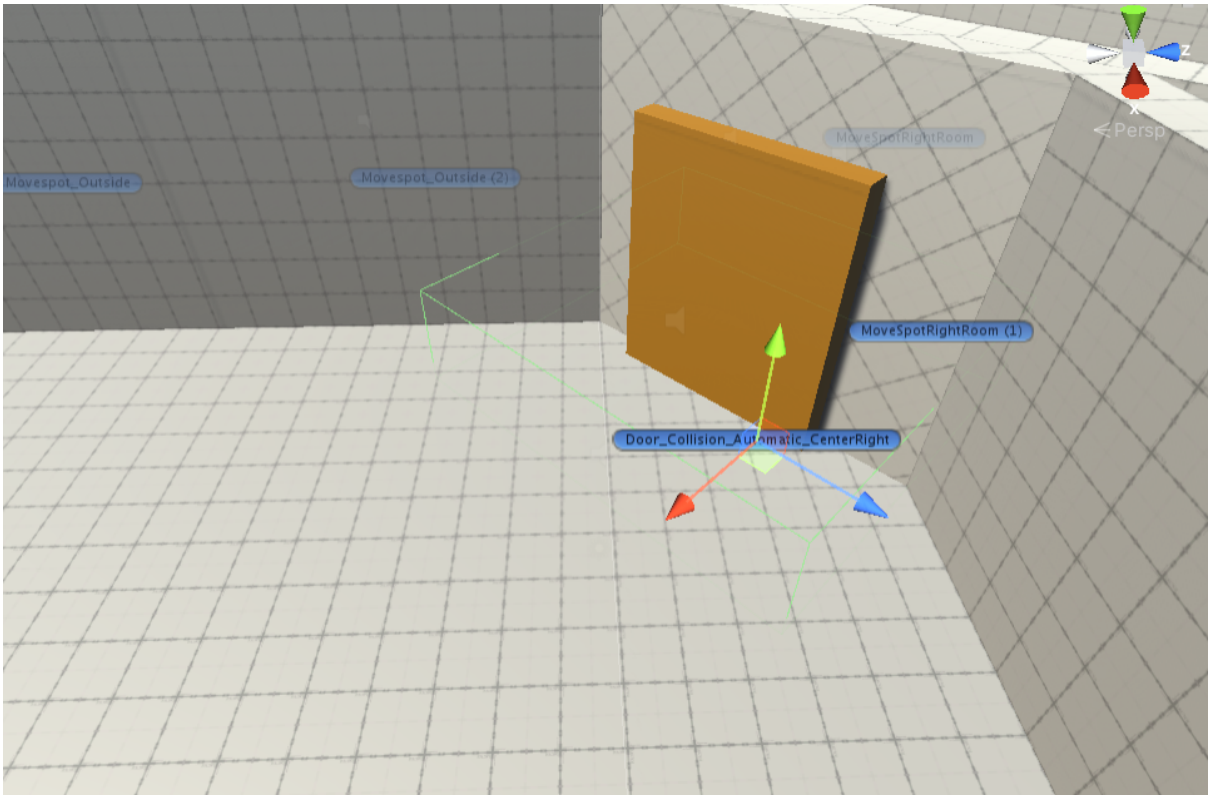


Figure 12. A door separating the rooms. The green box on the image appears as the trigger box, where when players enter or exit the box, the door will appear or disappear and the accompanying sound is played.

The player character could move freely within the game space using the WASD keys to move forward, backwards, left and right while the mouse was used to control the view direction while pressing the left mouse button would produce the sound of a gun firing and instantiate a bullet prefab. As a first-person shooter script was selected from Unity FPS Microgame Template, the feature of shooting was supplemented with a sound of the gun cooling off when the player had shot a specified amount of bullets, where the ability to shoot would temporarily be disabled until the 5-second clip had been played till the end. This was left in the first version of the prototype, as we presumed it would supplement an additional layer of realism as well as appear as a traditional shooter.

The movement and shooting controls are widely standardized within the FPS genre and hence it would appear natural to testers to use these keys as no tutorial nor key binding menu was enabled to decrease the complexity of the prototype. While the player character was used by way of an FPS template, an aim cursor image was incorporated automatically in the middle of the screen to signify that the player was holding a gun which they could shoot with.

The Escape key allowed players to exit the game.

Throughout the game, a grey overlay appears across the screen to prevent players from navigating with the visuals of the game level. This overlay could be enabled by pressing the “0” key, although it’s intention for disabling was only used during game development for the researchers to playtest sounds and game functionality. The play testers were not told that they could disable the game overlay.

When starting up the game, a grey screen appears with the words “Start Game” in the middle of the screen. Whenever the player moves their mouse cursor across the Start Game text, a beep is heard to inform the player that this Interface element is interactable, and another, deeper beep is heard when the start screen is pressed to inform the player that an action has been performed. The intention of the start screen is to allow the play testers the ability to prepare themselves and for the researchers to prepare equipment if necessary, although further presenting the prototype as a standardized game to be played at their own leisure. In the event the researchers would obtain a play tester with visual impairment, it was necessary to have the interface prepared for such in regards to sound feedback.

Figure 13. The UI overlay once the player enters the game.

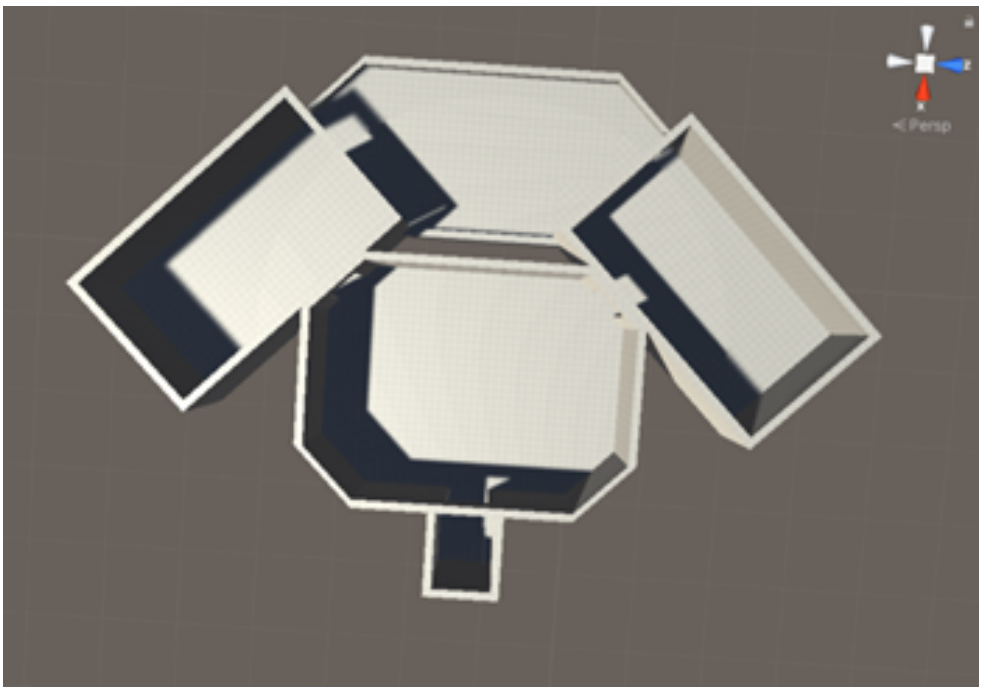
Figure 14. The UI overlay once the player interacts with the game.

Figure 15. The UI overlay once the player has interacted with the key object.

Once the player entered the game, text would appear at the top left corner, informing the player that their objective was to find a key. The intention of the text served as a reminder for players what the objective was and remained in the event the players would become overwhelmed by the lack of visual, sensory confirmation. We were additionally concerned whether players would believe their hardware screen was turned off or the game was broken if they were met with a black screen, and so the text was recognizable as they were playing a game.

Unity's UI Accessibility Plugin was incorporated into the user interface to ensure that the text could be read with screen readers if necessary.

The key and the enemies used 3D spatial sounds, where the volume of the individual sound would rise when the player walked closer towards the source. Interface sounds such as the feedback sound from the start menu as well as the feedback sound from reaching the objective were presented as 2D sounds as they had to be heard anywhere within the game.



(Figure 16 - layout of the first prototype. Top-down view)

Enemies

Once the game layout was implemented into Unity, game features and functions were implemented alongside. The enemies provided by the Unity FPS Microgame Template proved too complex for the initial prototype and new enemies were programmed and inserted into the game. Three enemies could be found in the game with one situated in each of the three rooms excluding the starting room, where they moved between three fixed points in the room. When the player reached within a specified radius of the enemy, the enemy would pursue the player. A health system was implemented on the enemies to ensure that the game objects could be pursued and destroyed by the player. During the test sessions, the enemy was programmed to be defeated as soon as they were shot with a singular bullet by the player. It was presupposed that the players would find it difficult to aim and shoot at the enemy as they would have no visual indicators informing them of the enemy's location. Furthermore, if the player needed to shoot the enemy several times in order to defeat them, a sound system informing the player whether the enemy had been hit or not and how low on health the enemy was needed to be incorporated to avoid misunderstandings or confusion from the player. However, as the initial prototype consisted of a simplified level with few sounds, the additional health and sound system was not implemented.

The intention of the enemies was an added obstacle and objective for the player as players could choose whether they wanted to eliminate the enemies. As the player would only be notified of the enemy's location through audio in regards to footsteps, it was important to ensure the enemies were easily eliminated to avoid further difficulty of the prototype. Therefore, the enemies would be destroyed from a singular hit with the weapon where they would then produce a death-sound in regards to a groan of a higher volume than the surrounding sounds in order to inform the player that the enemy had been eliminated.

The enemies themselves could not injure the player as no health system was implemented onto the player character. We speculated the initial prototype would appear too complex as players in turn would be distracted or overwhelmed by the depleting health of the player character.

Furthermore, adding extended complexity to the prototype would diverge from its intended purpose of observing navigation within the game world.

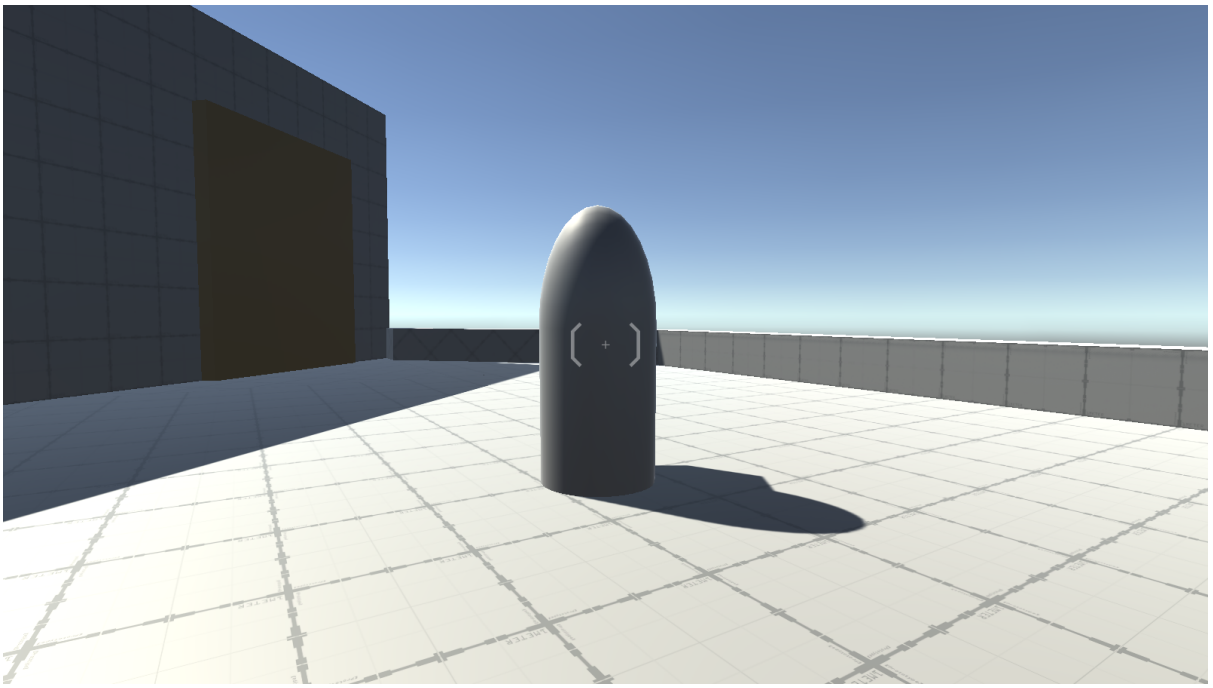


Figure 17. The enemy object as found in the game.

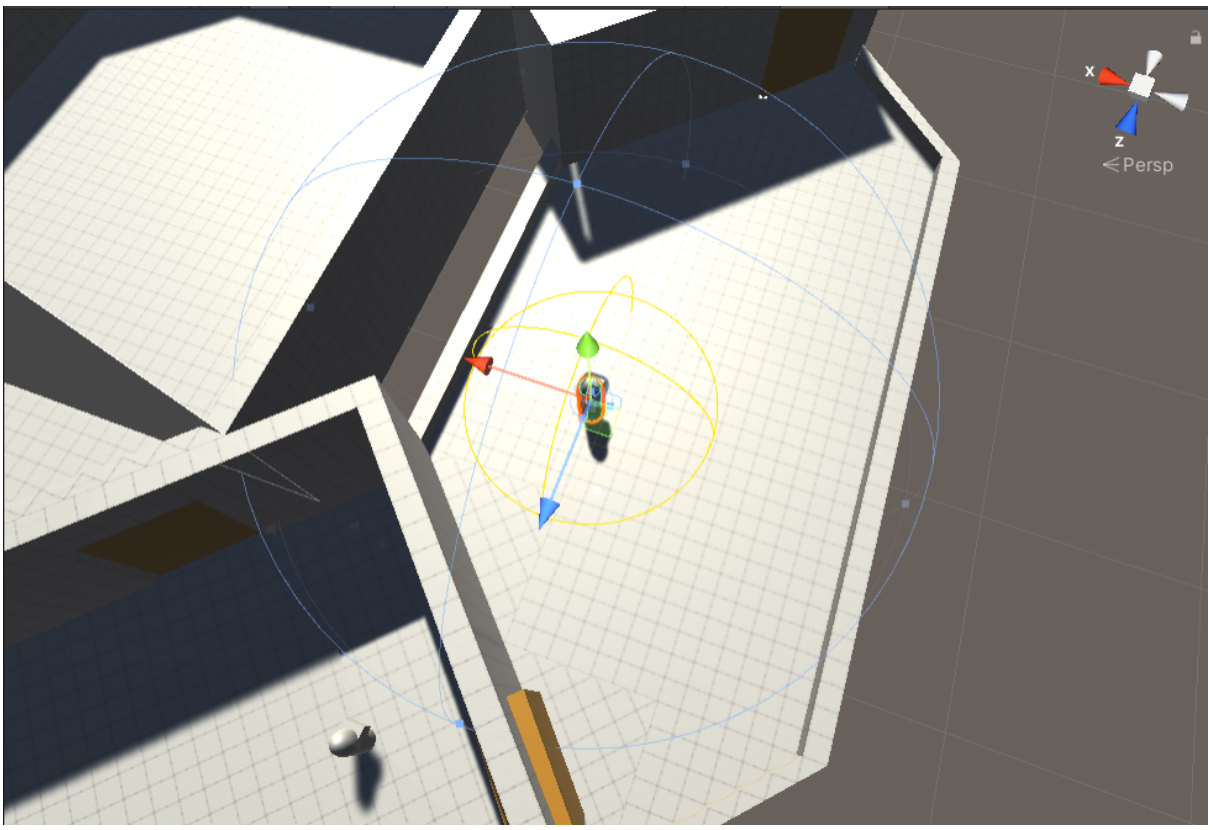


Figure 18. Enemy showcasing the various range parameters. The blue circle indicates the audio range i.e. when the player steps within the blue circle, they start to hear the enemy walking. The yellow circle indicates the range where the enemy will start chasing the player.

Objective

The goal presented within the game was a singular task of finding the objective, also referred to as key. During development, the player was to find the key and then an exit to complete the game. However, due to concerns that this would complicate the gameplay and potentially increase playtime for player testers, the objectives were reduced to a singular task. The key was scripted to appear in either of seven locations upon loading in game. The intention of the randomization of key object locations considered situations wherein the game would be playtested multiple times. Once the key had been collected, a brief sound was played to inform the player that the game had been completed while accompanied by a text saying “you win”. The intention of the “you win” text remained as a visual confirmation to players that the game had been won. Other alternatives to explore could have been to simply close the application or merely have the sound play, however, in order to minimize confusion from play testers, the text remained. This would additionally provide an opportunity for the group members to observe when participants had completed the game prototype during test sessions.

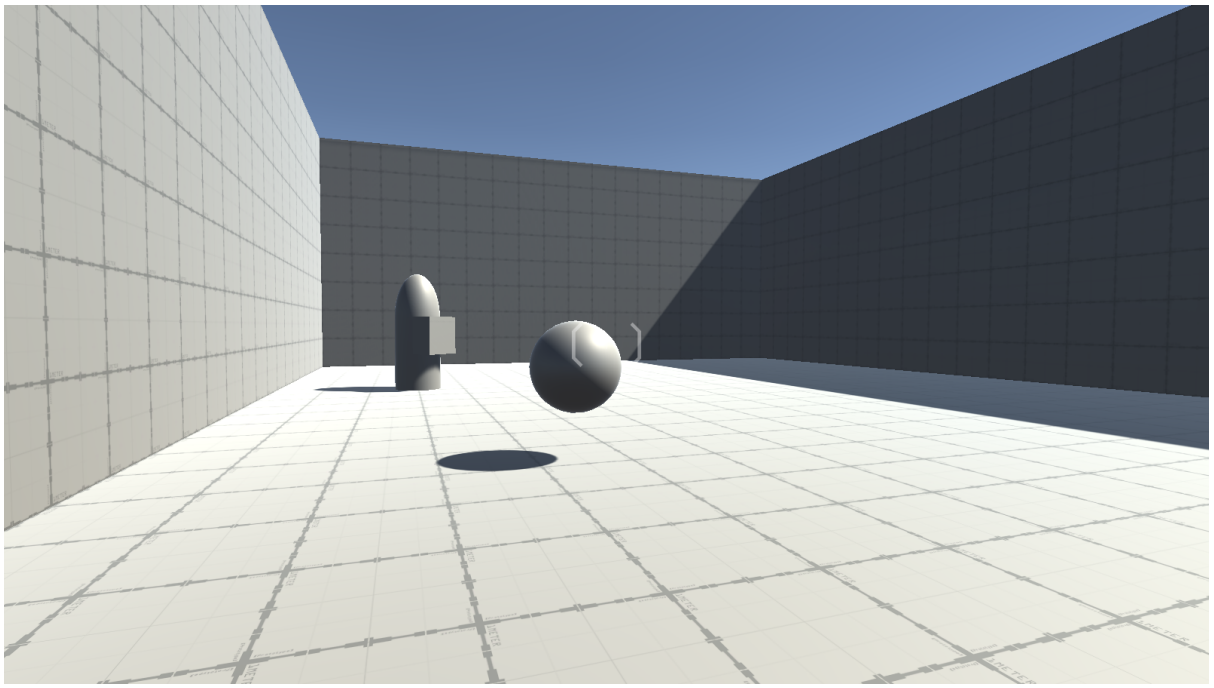


Figure 19. The object representing the key and an enemy. The key would appear in either of the three rooms containing enemies, and so the players would always encounter an enemy during their playthrough.

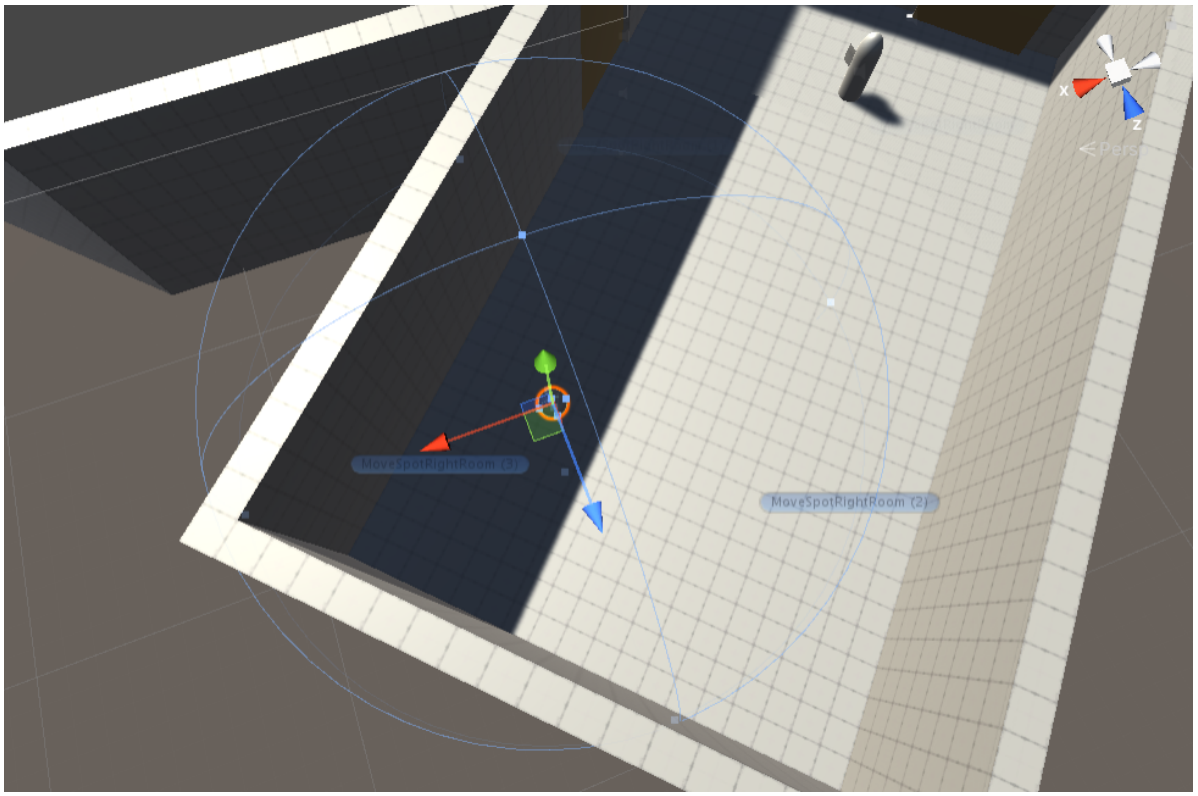


Figure 20. Sound parameter for the key object. The blue circle indicates the audio range, where whenever the player steps into the blue circle, they will start hearing the sound which in turn gets louder the closer they step towards it.

The second prototype

After testing the first game prototype and evaluating the feedback we had received from the interviews that were conducted during the test sessions, we made some changes on the game layout and sounds. Some changes were iterated based on the feedback from our test participants, while others were made based on observations through the test sessions.

Room overview

The first significant pattern we had observed was the test participants' navigation throughout the level. As we had been observing how they maneuver around the space, we could conclude that the level's layout seemed confusing to navigate. Most of the walls were diagonal and as the test participants went into the level without any knowledge of the level's layout, apart from one tester, they seemed to assume that the layout was more square with straight walls.

This was additionally confirmed to us by multiple test participants when we showed them the layout after they had already played through the level:

> Participant B:
>
> Yes, I thought it was way bigger and I thought I heard way more doors than there were. And I also thought that the rooms were smaller, actually. It does surprise me, I expected it to be much longer. Like wider, like, I was expecting long halls with doors on each side.

> Participant E:
>
> It surprises me that it uses diagonal stuff, because I didn't think that - I don't know, that seems a bit complicated to me

> if you don't have any kind of visual. I was moving in like only the four directions, or at least trying to.

Because of this confusion we decided to remake the entire layout of the level. We stuck to the same number of rooms that we had used in the first prototype and the placement of the rooms were somewhat the same, however, we made each room more square with no diagonal walls. The overall layout became one big square where the player would be able to walk in circles without being able to wander off to a far off corner and not be able to find their way back to a door. The path throughout the level became more linear. Designing the layout this way made it easier for the player to navigate to the next room even if they decided to explore as the rooms would almost guide the player to the doors.

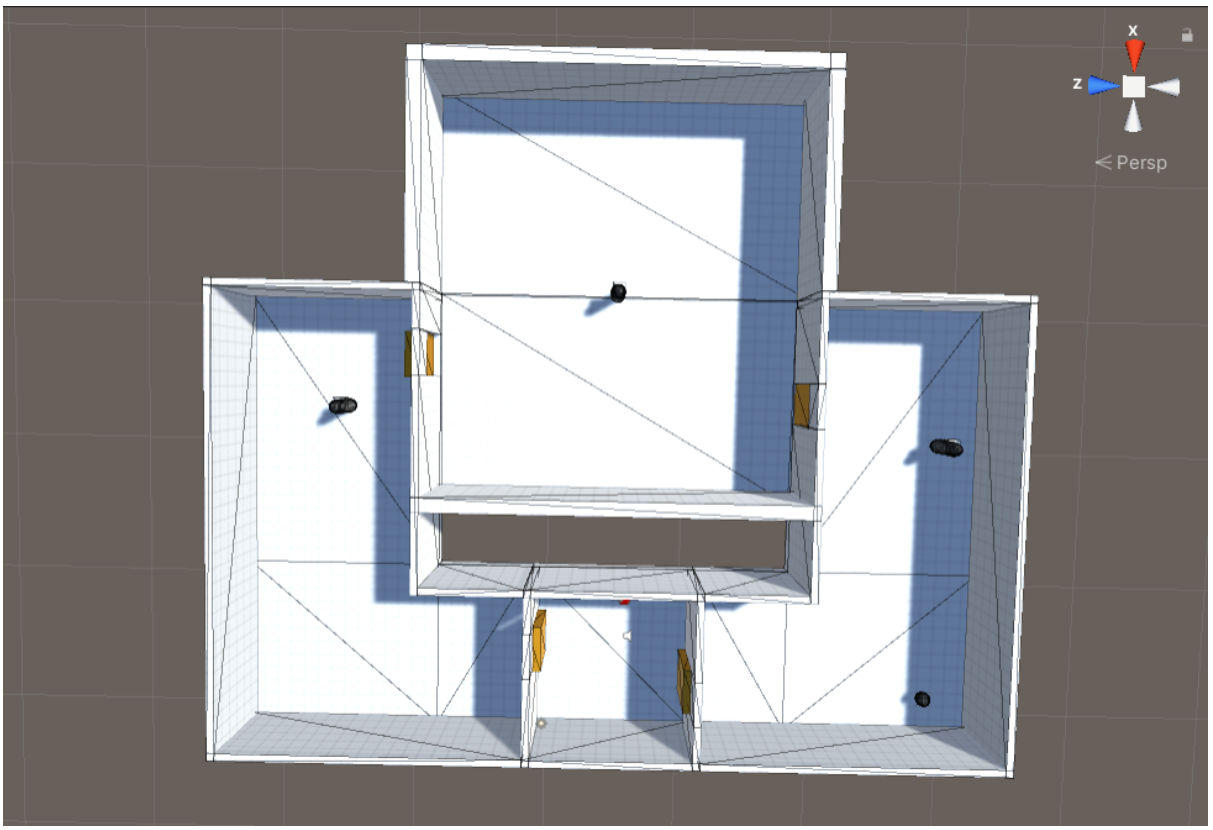


Figure 21. Room layout of the second prototype. Oblong shapes in each of the rooms represent the enemies. The sphere in the bottom right corner is a placeholder for the key.

Sounds

Another change that was made based on the test participants' feedback were the sounds. The sound of the enemies was changed as by the time the first test session started it was not how we actually wanted it. The sound we had uploaded in Unity seemed to change for unknown reasons in the build and instead of the slow footsteps we wanted it ended up sounding more like a quick clapping noise. This noise also seemed to confuse some of the test participants – one person commented that they thought it was the key.

This could be due to a couple of reasons, 1) the sound did not sound like a recognizable thing e.g. a hostile creature, and 2) the sound of the key was too quiet and unrecognizable as anything important.

In order to make the enemies sound more like a typical enemy from a video game we decided to record the sound of a Zombie in the video game *Minecraft* (Mojang, 2011). As the prototype is only used for testing and not being publicized, we believed that this sound would be better suited than the one we used in the previous version of the prototype as both *Minecraft* and Zombies are very popular in the video game world.

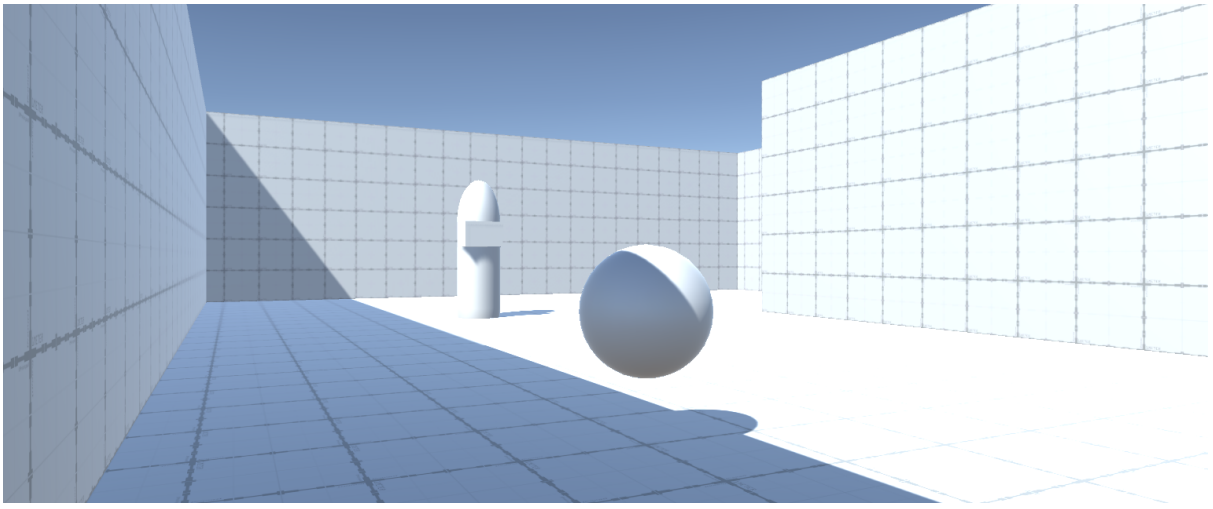


Figure 22. Enemy and the key.

Other sounds that were changed were the footsteps of the playable character. The first prototype only had one type of footsteps sound that was taken from a plugin in Unity and already during this version of the prototype we discussed the possibility of adding multiple sound files for footsteps that would change depending on the room the player would enter. We decided that during the first version this was not the most important sound to focus on as

long as the player could hear that they were walking. However, during testing there were some feedback suggesting that being able to better distinguish the rooms the player was walking in from each other would be really helpful for better navigation and knowing where they had already been:

> Participant A:
>
> I would definitely- there were, four, five rooms? I would almost say a sound for each room, if that makes sense. Like. for example if it is marble floor or something, then have a marble sound, if it is like a fuzzy carpet, have a fuzzy carpet. I feel like, the fact that the door sound is the same and the walking sound is the same, I am not really sure where I am in. Either that, or maybe like a gentle music in the background of some sort to kind of signify oh, I have been here before and then you can go back out like ok, I have been here before. What room do I need to go to? That would also make it easier if I want to play the game again, then you could figure out ok, I know there's an enemy that's going to spawn somewhere near in this room along those lines. (...)

Therefore, for the second version of the prototype we decided to add in multiple sound files for footsteps so that when a player entered a new room the footsteps would change. These sounds were also recorded in *Minecraft*, like the enemy sound was as it was easily accessible to us and the footsteps were easy to distinguish from each other. We recorded the character walking on grass, stone, sand, and wood. Each sound was then applied to each their own room through Unity's tag system. Whenever the player character collided with the box collider attached to the room, the script attached to the player character would register what tag was applied to the room, where it would then replace the current sound file for footsteps with the sound file attached to the tag. The game layout of the level additionally needed to be remade, due to the Unity plug-in Probuilder disallowing the separation of walls and flooring, which was necessary as it was important that a different sound would play whenever the player collided with the wall versus walked on a different type of terrain.

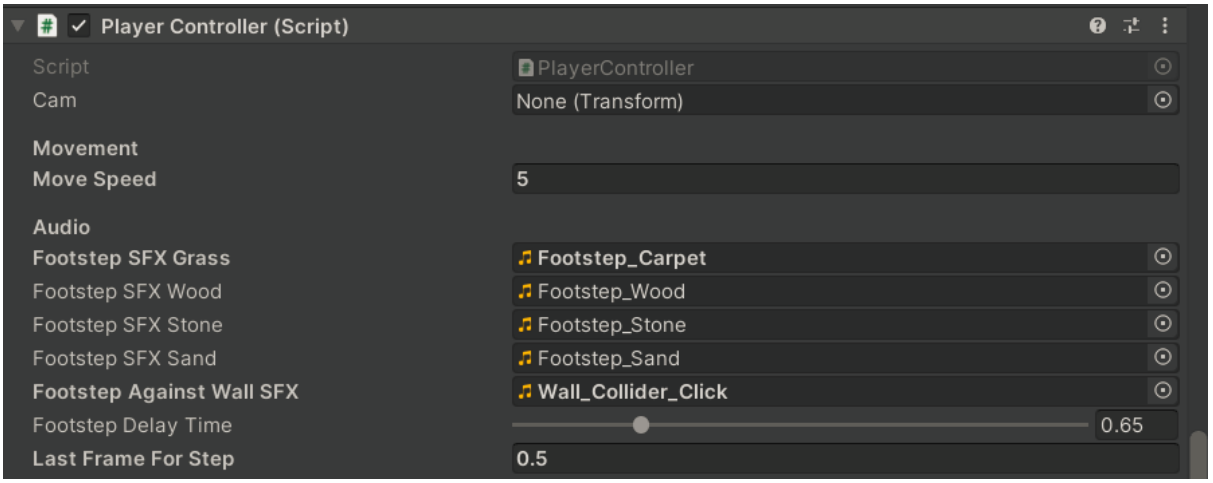


Figure 23. Inspector for the Player Controller script attached on the player game object. Dependent on the type of flooring the player character would move onto, that sound would be replaced as the audio clip on the audio source component within the same game object

Another one of the main sounds that were changed was the sound of the player walking into a wall. This sound confused a few of the test participants in the first test session. One person said that they confused it for an enemy shooting at them because of how loud it was and reminded them of gunshots:

> Participant D:
>
> I think if the wall collision was a little quieter, then I might not have confused it for gun fire, for me at least.

The sound for walking into a wall was initially a different version of the footsteps sound and therefore, to some participants, it was not clear that they were not moving anymore or whether they were moving against an obstacle or merely walking, which counter-acted the point of the sound being there in the first place:

> Participant B:
>
> Yes, except for when I was walking into a wall, and when I wasn't, sometimes I couldn't tell the difference if I was

walking into a wall or if I was just walking, until you told me, or until I asked.

For the second prototype version we therefore decided to change this sound to a completely new sound. We found a sound in one of the first-person shooter plugins for Unity that sounded more like a click sound. This sound was short and clear and therefore not too intruding and distracting from other sounds. The click sound was also more distinguishable from all the different variations of the footsteps that we added into this version than the previous sound from the first prototype. It was important to us that this new wall sound could not be mistaken for a fifth set of footsteps as we believed that that could cause even more confusion than previously.

Furthermore, the player character gameobject had to be remade, since, as mentioned previously, the player character was a fully-functional FPSs script derived from the FPS template and thereby possessed features which were not incorporated into the second game prototype that was constructed. One such feature was crouching, which was discovered by one of the test participants, and which when performed made the sounds malfunction.

As mentioned previously the sound of the key might have been too quiet and unrecognizable. The feedback received during the first test session about the key sound was a bit mixed – some test participants could not hear the key at all, while others did hear it but did not expect it to be the key and therefore did not find the sound important as it was very faint and wind-like:

Participant B:

No, until you told me, or until I asked, I thought it was just ambience. I was expecting the key to have a sort of, like a pling sort of sound, like a metal-ly sound, like when you pick up those rings in Sonic.

Participant G:

I think I heard it the first time. I just wasn’t sure that was the key, because if I imagined the sound of a key, I would be like KIIING or some sort of metal sound or a sharp

> sound, and this was a very soft and round, so I think because I just expected something else, it kind of made me not realize the sound of the wind was the key, because I expected something. (...)

In the first version of the prototype the key sounded a lot like wind. We had initially intended this as being a placeholder sound until we found something better to use and the feedback we got on the sound confirmed to us that the sound needed to be changed. One test participant mentioned that having the key sound more like jangling keys would have been more expected and would have made them more aware that that was probably the objective they were trying to find:

> Participant G:
>
> (...) I feel like the WOOSH sound is good (...) because then it's like oh, something's happening. Oh okay, this is new and new is good, because that might mean key so the closer you get to the key, the more the sound is distorted or changed so maybe that's where the clinging sound comes from, or like, dropping a bundle of keys or a sharp THING. I feel like the wind is good, it's just more like a trying to catch my attention bit, not so much, here, I'm the key.

Because of this we replaced the windy sound for the key with a sound of a set of keys jingling in the second version of the prototype.

An additional sound which was iterated upon was the sound indicating that the player had found the key and therefore won the game. The sound for the first prototype consisted of a short laser-like sound which was merely intended to be a sound effect informing the participants that the state of the game had changed, as the accompanying UI overlay would change towards a 'You win' text as well. Counter to us trying to make the prototype accessible, we had not accounted for participants playing with their eyes closed and therefore not register the alteration of the UI overlay text. The players who played with their eyes closed expressed confusion as they did not understand what the sound meant and therefore made presumptions based on their interpretation of the sound:

Participant A:

No. I thought I had reached some kind of bad ending because suddenly I heard the sound of space, and I thought I had opened up a door to I have yet to be in and I thought there was going to be a massive boss or something and that was why I heard the sound of space because I was going to defeat a space monster of a massive size. I could not tell at all that that was the key. Like, if I were to expect a key sound, I would expect a more victory kind of sound, and not a emptiness kind of sound. I felt very lonely all of a sudden.

Other participants wanted the sound to appear more victorious as to congratulate them for finishing the game and keeping them engaged:

Participant G:

(...) I don't know if you could do like a , some sort of overwhelming sound (...) but like an indicator that you found the key

Interviewer:

There is a victory sound

Participant G:

Yeah, I heard it but more like a longer lasting victory. (...) I don't know, of course it's satisfying, because the game is so hard, so of course it gives you this satisfaction of finding it, the key.

Participant F:

(...) And I think the reward of killing an enemy or the reward of finding a key should be like BAAM. They were too subtle. But the shooting sound was a bit too, in my face.

Therefore, the sound was changed from the simple sound effect to a four-second long fanfare in order to inform the players that they had completed the game.

A few of the test participants had difficulty locating the enemies when they got close as it was hard to hear exactly which side the sound of the enemy was coming from. We made a few tweaks to the volume of the different sound files and this seemed to help the issue a bit, however, looking into Unity's 3D sound we believe that we could make this even better for future versions.

During the first test session, one test participant managed to finish the game by accident within one minute, which we believe was due to the key spawning right in front of a door. For the second prototype version we therefore changed the spawning locations of the key so spawning in front of doors was no longer possible. This meant that the player would actively have to listen for the key and the probability of accidentally finding it – also due to the key sound change – was less likely.

Results

The following chapter presents the results obtained from the playtests on the prototype as detailed in the methodology chapter, along with an analysis and discussion of the presented data. The discussion considers the results in regards to the utilized methodology, earlier literature and research presented and related theoretical framework, thereby supporting obtained findings and understanding player navigation in a game world consisting of limited visuals.

The chapter separates the quantitative data gathered from the qualitative data, wherein the data will firstly be examined based on direct observations. Afterwards, a comparative evaluation and discussion on patterns arising from the information gained through the post-gameplay interviews will be conducted.

It is important to consider technical issues encountered during post-gameplay interviews, such as recording equipment failing to conduct recordings of participant test sessions with consequences of data being viewed as unusable and invalid due to the incomplete presentation of the original data. However, despite the incomplete presentation of data, the information gathered from test participants provide insight into player navigation and support significant patterns observed in their interactions with the audio-based game world.

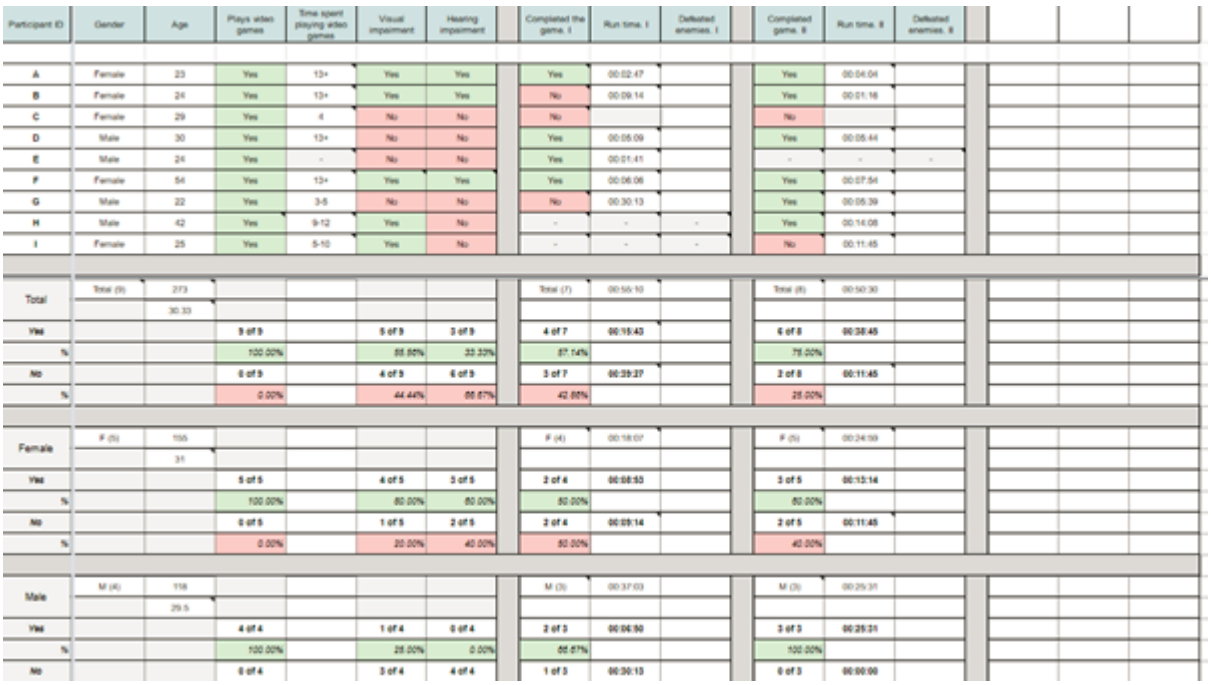
Similarly, during the test session of the first prototype, participant A conducted the playthrough using Unity build 0.4, which was later patched for the other test participants to use Unity build 0.5. The patching was intended to remove a bug wherein the player was at risk of being pushed out of the game level by the enemies, as experienced during the playtest with participant A. With a previous build version than the overall participants, the data received from participant A can consequently appear as invalid due to their experience being influenced by the bug. However, as the case with the post-gameplay interviews wherein the recording equipment failed, the data received from the test session with participant A nevertheless provide an insight into factors of game navigation and experience of the audio-based gameplay.

Therefore, the data will be included in the presentation and discussion as a collective insight into participant navigation patterns along with the data gathered from the additional playtests.

Quantitative session data presentation

Data collected before the gameplay section of the test sessions was reviewed and managed into a table. Alongside the representation of the demographic categorization, an arrangement of each test participant's time dedicated to completion of the game prototype is presented as well as the amount of times the test participants played through the version of the selected game prototype. Completion time of the game prototype was measured from when each test participant first clicked on the Start game button in the main menu and thereby entered the game, and until the You Win UI overlay was enabled from interacting with the key object or if the player voluntarily forfeited the game. Regarding completion of the game, a test participant would be labelled as not having completed the game prototype if they either forfeited finding the key object or if they disabled the UI overlay to view the visuals.

Gathering the quantitative data alongside each other enabled an overview of all participant statistics with the intention of investigating any revelatory pattern that could arise. Figure 24 represents the quantitative data gathered from test sessions version one and version two, which were performed either online or locally, on a total of nine different participants, of which most were performed on the same participants:



(Figure 24 – Table containing quantitative data gathered from test participants, including their completion time, whether they completed the prototype or forfeited and how many enemies the participants defeated during their playthrough. Appendix 4, pp. 14-17)

Each of the nine participants played through the game, although some were introduced to the game through the second prototype, iterated game version while one of the participants from the first test session was unavailable for testing of the secondary version of the prototype. A gender differentiation regarded the participants as five females and four males, with ages ranging from 22 to 54 years. The data collected showed collective characteristics wherein all test participants confirmed playing computer games, although time spent playing computer games on a weekly basis ranged between 1-2 to 13+ hours. An exception concerns participant E, who explained in the pre-gameplay interview that their time devoted towards playing computer games was contingent on how much spare time they had remaining from their occupation.

A notable observation presented in the overview of the questionnaire data illustrates a significant number of participants explaining to be affected by a type of visual impairment of five out of nine participants. Of the female participants, four out of five describe to be affected by a type of visual impairment while one out of four males explain to be affected by a type of visual impairment. It should be acknowledged, however, that while five out of nine participants experience a type of visual impairment, the participants' experience of visual impairment does not complement the definition of visual impairment, serving as a definitive explanation for the term's function in the project. The definition chosen refers to the

decrease in ability to see, wherein the degree of reduced vision affects a person's daily life and the cause is not fixable with glasses. All participants experiencing visual impairment would proceed their daily lives unaffected with glasses, with the exception of participant B. They expressed that the visual impairment affects their perception of small font sizes as well as small graphical details if either playing during the night or if they are seated too far from the screen. Regarding the participants' experience of hearing impairment, three out of nine of the participants explained to experience a type of hearing impairment, where all the affected participants were females. Both participant A and participant F were sensitive towards certain sounds, while participant B and participant F experienced tinnitus within both ears. Furthermore, participant F experienced a high-pitched ringing in their right ear, while participant B's hearing was ten percent lower than the average human hearing.

An interesting difference in the test participants' results regarding completion time of the game prototypes reveal a significant amount of players completed the first game prototype faster than their playthrough of the second game prototype. Most of the test participants took longer to complete the second prototype of the game with the exception of participant B and participant G. Participant B completed the second game prototype 7 minutes and 58 seconds quicker than their playthrough of the first game prototype. On their playthrough of the second game prototype, participant G completed the game 24 minutes and 34 seconds quicker than their first playthrough.

Regarding the other test participants' completion time, the completion divergence between the first and the second game prototype lies around 1 to 2 minutes, with the exception of participant H and participant I who both played through the prototype beyond 10 minutes before either finding the key object or forfeiting the game.

Another revelatory difference apparent in the data overview illustrates a higher number of test participants completing the second game prototype than the first prototype, wherein three out of seven participants could not complete the first prototype for dissimilar reasons, while only two out of eight participants could not complete the second prototype. Both participant B and participant G did not complete the first game prototype, albeit they completed the second prototype. However, participant B explained upon removal of the grey overlay within the game once they had forfeited the task, that they did not know the game camera could be repositioned with the mouse cursor, since they had presupposed the player character would turn dependently on the movements keys.

A similar observation regarding object completion was presented when comparing the amount of enemies that test participants defeated in the second and the first game

prototype. While both participant D and participant G defeated all three enemies in both prototypes, the other test participants presented an increase in the amount of enemies they defeated by either one or two. The most significant difference emerges with test participant F who only defeated one enemy in the first prototype, but managed to defeat all three enemies on their first playthrough of the second prototype.

During the interview prior to the gameplay section, the participants were inquired what games were their favourite. The intention was to establish connections between what games they found enjoyable and their approaches and behaviours towards game elements, such as how the participants reacted towards the enemies. The participants replied a variety of game titles across a diverse range of platforms, whereas game titles such as Subnautica and Stardew Valley appeared twice. The games were divided into categories of platforms, wherein the most common platform used to play their favourite games was PC platform and PlayStation. The favorited games were categorized dependent on genre as well, wherein it was revealed that the role-playing genre appeared most frequently with six entries, while shooters appeared as another frequent genre with five entries.

Qualitative session data presentation

Data obtained from recorded post-gameplay interviews of test session one and two were transcribed and gathered. Thereby, providing the opportunity to observe significant patterns arising from the test participants' answers in accordance with their experiences of the game prototypes. Appendix 4 (pp. 18-64) presents the transcribed answers participants provided during the interviews of both test sessions, wherein all participants' answers are presented underneath the investigative question. An overview presentation of the participants' answers will be separated into the first and second session with the purpose of evaluating any comparisons or dissimilarities revealed in the participants' responses between the two test sessions. Seven test participants completed the first test session, while eight were available to complete the second test session.

Presentation of data from first test session

An examination of the test participants' answers reveals that in regards to navigating through the game level of the first prototype, most of the participants felt confused and uncertain in

their navigational ability. Participants responded that they were unsure what direction they were proceeding in and what each of the sounds signified. Nonetheless, participant B and participant F explained that the navigation became easier once they listened to the sounds or were told what each of the sounds signified. Furthermore, three of the seven participants were revealed to create spatial cognitive maps of the level as they navigated through the prototype.

When inquired whether the participants could tell the layout of the level, a pattern seemed consistent within the participants' answers of being unable to perceive how the layout of the game level was structured when navigating through it. Afterwards, when the participants were shown an image of the layout of the level the participants had been navigating in, they responded that they were surprised by how it was structured. Both participant A and participant B pointed out that they had imagined the layout structured like a corridor with the size of the level being much smaller than presented.

Regarding the objectives of the game prototype wherein participants were asked if they had defeated any of the enemies, a significant dissimilarity emerged from the participants' answers. Three out of seven of the participants were sure that they had defeated enemies throughout their playthrough, while three out of seven of them responded that they thought they had defeated enemies. Participant F explained that they knew they had defeated the enemy because the interviewer had informed them of it.

In the inquiries concerning the key objective, most participants were able to locate the key, although many of them commented that in terms of hearing the key, they were unsure what the sound signified. Participant E and participant F explained that they merely reacted to the change in audio as a new sound was introduced to the game world, while participant B presupposed the sound to be a type of ambience until told otherwise by the interviewer.

When asked whether the participants could distinguish the different sounds presented, all participants commented that they were able to distinguish the sounds from each other, albeit participant B and participant D explained that the sound for hitting the wall had confused them initially, while participant F commented that they understood the sound of hitting a wall fairly fast. Regarding the spatial location of the enemies, a contrast in the participants answers seems apparent as both participant G and participant D explained that they were able to determine the location of the enemies while participant C and participant F explained that they could not.

A notable distinction in the participants' responses occurred when inquired of the balance between the various sounds volumes, wherein the participants shared differing opinions in which sounds were perceived as too loud or too quiet. Participant A, participant E and participant F explained that the sound for shooting was perceived as too loud, while participant G commented that the shooting was pleasant. Participant D commented that the audio level of the wall collision sound could have been lowered slightly as to avoid confusion while participant F believed the sound of the doors, the sound signifying an enemy's defeat and the interaction with the key should have been louder.

When asked if participants had played similar games as the game prototype presented, all participants answered that they had not played audio-based games before, albeit some of the participants explained examples of games wherein the audio played a crucial role in the gameplay, such as Slender (Parsec Productions, 2012), Five nights at Freddy's 4 (Scott Cawthorn, 2015) and Thumper (Drool, 2016).

Presentation of data from the second test session

Concerning the test participants' experience of navigating through the game world in the second session of playtesting, a similarity was found within most participants' answers where they experienced uncertainty regarding the direction they were facing or navigating towards. Participant A explained that the sound of differentiating footsteps aided their navigational ability throughout the game, albeit they were still uncertain what direction they had the player character turned towards. Both participant F and participant G responded that the ability to navigate had improved from the first test session, while participant D stated that they felt more confident navigating in the second prototype.

Regarding perception of the game level's structure, most participants explained that it was unclear where they were navigating towards within the game world. Participant A explained that navigation came easier once they stopped trying to think of where they were currently and instead simply walked towards the sound. Participant G explained that they pictured the game level as bigger in their head than was presented within the game level.

When shown an image of the game level, participant I and participant C explained that they imagined the game level as bigger, while participant B expected a reused layout from the first prototype.

A notable observation of the participants' answers reveal that they were all certain they had defeated enemies when inquired. Furthermore, while participant B thought the iterated sound the enemies produced was scary, participant H explained that they found it creepy, although it made them want to pursue the enemies. Similarly, participant F explained that they wished there were more enemies as the enemies provided the best component of the gameplay. Participant D commented that they recognized the sound of the enemies, which they initially thought was humorous, although they further noted that the sound increased the suspense of the gameplay when they heard the enemies move closer towards them. Regarding the test participants' ability to locate the enemies, participant B, participant C, and participant D commented that they experienced difficulty in finding the enemies' location regarding whether they were in front or behind the player character. The other participants explained that they could sense where the enemies were located.

Another significant observation illustrates that all participants reacted positively towards the iterated sound signifying the key, while participant G commented that finding the key was easier in the second game prototype. Both participant B and participant H expressed that they conjured a mental image of someone walking around in the level with a bundle of keys. When asked whether the participants could hear the key within the game level, the participants responded that they were all able to hear the key.

Most of the participants were able to distinguish the various sounds within the game level from each other, albeit each participant expressed uncertainty towards certain sounds. Participant A, participant C and participant G commented that the iterated sound for hitting a wall confused them, albeit participant D explained that they quickly knew what the sound signified. Participant B expressed that many of the sounds obstructed each other, and they were therefore confused when presented with the door sound in regards to whether they had already passed through the door and into a new room. Participant G revealed that they were not aware of the different footsteps occurring throughout the game level, as did participant B in relation to another question, while participant C explained that they were aware something within the audio had changed although they were unsure what it had been. Participant F expressed that they noticed the different footsteps.

Regarding how the test participants perceived the balance between the audio levels of the game prototype, the participants provided various responses for what sounds they perceived as available for improvement. Participant B explained that they believed too many sounds were introduced at the initiation of the game whereas they wished to have a singular sound introduced at a time. Participant C responded that the monsters were too loud, while participant D explained that both the monsters and sound for the key were too loud.

However, participant D further commented that they believed this was an acceptable sound level, as they were able to perceive the sounds from the other rooms, albeit they believed it would improve the gameplay if the sounds were muffled so players could indeed tell that they came from the next room. Dissimilarly, participant F believed that the sound for the key as well as the enemies should appear louder.

When inquiring what emotions the players experienced when playing the second prototype, participant C expressed that they felt confusion and disorientation when navigating through the game level, which led to frustration. Participant D expressed they felt confidence from having participated in the first test session and thereby possessed knowledge of how to approach the game level. They further stated it was amusing to pursue the enemies as a secondary objective.

Discussion

Playertest evaluation discussion

The results obtained through the participant playtests of the game prototype identified several patterns of how players perceive and interact with the sound in-game and use audio as a navigational tool. The initial research question seeks to uncover how to present a concept of a world and a system to players using only audio as a navigational tool throughout the game and thus creating an experience. The following evaluation and interpretation of data gathered from the test participants discusses the findings within the thematic framework of the research question presented in the introductory chapter, regarding how certain audio cues engage and guide players within an audio-based computer game with limited graphics. Thereby, the following analysis on the participants' interaction with the prototypes will be regarded with the themes of navigation and player engagement.

Results obtained from measuring the playtime of the test participants reveal a statistically significant difference in completion time between the first and the second game prototype. This could conclusively suggest that the first game prototype provides preferable ground to navigate through the game level with the simplistic approach of allowing a single footstep sound to consist throughout the gameplay. However, this does not become apparent when comparing the success ratio of the second prototype versus the first prototype, wherein more

participants completed the prototype by finding the key object. It is important to consider the reasons behind the participants forfeiting the game, whereas the participants' approach towards the gameplay illustrates a goal-oriented attitude towards games. When the key objective could not be found, they forfeited the game. Regarding the test session with participant I, the player character had been proceeding against a corner for approximately 10 minutes, whereas they presupposed the game level was larger. However, as the game state did not change, they forfeited the game as well.

Furthermore, a significant pattern concerning the gamer type each participant inhabits reveals the participants' varied approaches towards navigating throughout the game level. Some of the participants expressed an interest towards pursuing the enemies of the game rather than completing the task of finding the key objective presented to them:

> Participant H:
>
> Yeah, they were breathing. They were annoying. It was kind of creepy to hear them breathe and you can't see them. That makes me want to chase them.

> Participant D:
>
> Yes, because I found it in the first room I went, and then was trying to avoid it to fight the other enemies.

> Participant G:
>
> (...) No, no, no, because there were two enemies that I couldn't find. I could hear them and I kind of chased them

As the participants pursued the enemies rather than the key object, this confirms that the added completion time could be a result of the participants seeking another challenge within the game. Therefore, even if the game layout was constructed to enhance participants' navigational ability, the participants themselves might express more interest and enjoyment towards experiencing the game layout rather than performing the tasks presented. Some of

the participants actively avoided the key object and instead explored the game world as that appeared more compelling to them.

Spatial navigation in an audio-based world

Observations regarding whether the audio cues presented within the prototypes supported the participants' navigational ability reveal contrasting results with how the participants utilized and perceived the audio cues. Some participants expressed continued confusion that seemed to persist from the first prototype and towards the iterated version of the second prototype regarding directional navigation. The participants commented that they felt unable to perceive which direction they were facing:

> Participant A:
>
> No. Again, I'm glad there were different sounds for the floor. That was a good help, but I still feel like there is direction problems, of like, where the sound of like going into a wall

> Participant B:
>
> I am still, unsure like, when I move the mouse around I have no idea like which way I am facing or like where I am, so I have no idea how much to turn left or right to actually turn and that confused me a bit

> Participant G:
>
> Most of the time, yes, it was better than last time. So, yes, eighty percent, the not knowing which direction you are walking when you look kind of checks the twenty percent off. But yeah, I would say, mostly.

However, results additionally illustrated that other participants expressed that they felt a heightened sense of confidence or awareness regarding navigation through the game level based on how they had experienced the navigational audio cues from the first prototype:

> Participant D:
>
> I felt more confident this time than last time, but last time I felt pretty good overall.

> Participant F:
>
> Yeah, I felt that I was more aware of where I was going, I had a better picture of the rooms this time. Like, I felt I went really quickly through a door and I felt like the enemy was to my left right away and I went through the room and I went to the right, so I had a better picture in my head.

Although participant D commented that they felt more confident with the navigation within the second prototype, they further explained how they attempted to map the layout of the game world, but when they turned their player character, they lost a sense of how much they had turned:

> Participant D:
>
> (...) in the first room when I was going to map out the layout and then I turned all of a sudden and I was like oh, I don't know how far I just turned.

The participants' replies seem to provide evidence regarding the need for awareness regarding directional navigation, as most participants completed the prototype, if provided with sound cues that informed them whether they were facing north, south, east or west, there is a possibility it could have resulted in a faster completion time.

As mentioned in the design chapter regarding the second prototype, assumptions regarding the addition of footsteps as an audio cue to signify the various rooms would aid player navigation were established. These assumptions were inaugurated based on participants describing a process wherein they developed spatial cognitive maps of the game level layout:

> Participant B:
>
> (...) But I had an image in my mind trying to like map it in my head, and that was top-down, so I also think that's why I didn't use the mouse because I just expected it to be top down.

> Participant E:
>
> I felt like I had to concentrate a lot on knowing which direction I was going in in like 360 degrees. Like, keeping a constant, like, mental map of, like, okay, where am I looking now? Is it south or north or west or east. And I couldn't- I didn't really catch what the sound for moving and what the sound for hitting a wall and not moving was.

> Participant F:
>
> (...) yeah, all of a sudden I had the level in my head, like the platform in my head.

These comments seem to support previous experiments regarding participants using the more reverberating audio cues to recreate complex spatial maps of virtual worlds to utilize as a navigational tool set (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014; Connors, Chrastil, Sánchez, & Merabet, 2014). The drawings depicting the game level layout produced by participants provide additional evidence to suggest that the participants indeed conducted and reflected on the game layout as they navigated through it.

Whether all participants constructed spatial cognitive maps of the layout cannot be confirmed due to the qualitative nature of the measure. However, when presented with a screenshot of a top-down view of the game level, all participants expressed surprise as if it was contrasting to their perception of the level structure:

> Participant A:
>
> I think what makes me an awful case in this situation is the fact that I already knew what it looked like, so I assumed I would be walking around in that. So when it didn't feel like I was walking around in that, my expectations were completely blown away. Cause I was unaware where I really was. Because everything felt like a small room. It felt like a corridor, but nothing here tells me it's a corridor. It's four big rooms and a ledge that you can easily fall over.

> Participant B:
>
> Yes, I thought it was way bigger and I thought I heard way more doors than there were. And I also thought that the rooms were smaller, actually. It does surprise me, I expected it to be much longer. Like wider, like, I was expecting long halls with doors on each side.

> Participant E:
>
> No because I- I don't know, I imagined it would be a bunch of corridors or some reason.

The participants' comments therefore additionally suggests a necessity for navigational audio cues, which would encourage spatial cognitive maps resembling the actual game level layout.

As explained in the design chapter, this type of soundscape is used in many games and the alteration of footsteps sought to improve player navigation and engagement within the virtual

world. However, data of the second playtest session illustrates that a considerable amount of the participants overheard the altering sound of terrain altogether:

> Participant B:
>
> Not at all. I just knew they sounded different and then I thought of heard a clinking sound and I thought that was maybe the sound of me hitting a wall or something, but no, I didn't notice that.

> Participant C:
>
> Yes, sometimes it was like gravel and something else. Yeah, it was definitely changing. Not I didn't know what that was, like, if that was a direction, a hint or whatever it was

> Participant F:
>
> After you instructed me, I could tell the difference in the steps, but if you hadn't, it was confusing, because there was sounds of the steps and there was a new sound of bumping into the wall which is also steps.

> Participant G:
>
> The difference of the floors, maybe turn that up a little bit, or make it more distinguishable, or something, because I think for me, because you are so concentrated and you think so much, you kind of overhear or maybe overlook the possibility of that, because I didn't notice at all, if you didn't tell me (...)

Providing a reasoning behind the footsteps being overheard, participant G explains this is likely due to the amount of sounds presented at once, wherein participants were

concentrated on one sound and ignoring the others. Participant B replied in a similar vein when inquired about the balance of the audio levels:

> Participant B:
>
> The enemies were a bit too much at the start. I felt like I was just thrown into it, and then I heard enemies, I moved a bit, I heard a door and then I started hearing the key. So I think the enemies were a bit too much. Maybe take more time to present one sound at a time so I get used to one sound at a time instead I felt like I had three sounds thrown at me at the same time and I trouble distinguishing between them.

> Participant G:
>
> (...) because I think for me, because you are so concentrated and you think so much, you kind of overhear or maybe overlook the possibility of that, because I didn't notice at all, if you didn't tell me. (...) And because we can't see anything, then the audio, we start listening more, so listening to a sound all of a sudden going SWOOSH just takes up all of our concentrating and all of like our capacity at the moment is that door, where am I, am I going into a different room, so you just, you have so many things going on, so you have the sound of the floor that is probably the last thing you think about, maybe making that a little bit more distinguishable would be great, otherwise.

This commentary by participant G provides evidence that the footsteps serve an unnecessary navigational tool, if not introduced properly. The reasoning behind the participants overlooking the sound of footsteps could likely be due to the fact the player will always walk through a door before the sound representing the current terrain is altered. The sound of the door itself informs the participant that they enter a new room and appears as a loud 2D sound, wherein it likely occupies most of the participants' focus for the crucial moment where participants must understand that the sound for the flooring has been altered.

Additional reasoning behind why the footsteps were overheard by participants could be a consequence of the footsteps functioning as auditory icons, where participants already recognize the sound from real life and therefore are more likely to ignore it (Jørgensen, 2007). Thereby, the sound for hitting a wall appeared as abstract for the participants as they had a difficulty understanding what it meant, although some participants seemingly learned what the sound signified:

> Participant D:
>
> It was a lot better than last time. Again, not knowing what the sounds were took me a minute, because first the footsteps sounded like hitting the wall previously. And so I thought I was hitting the wall, but then once I actually hit a wall, I realized that that was probably the wall sound and that the other was footsteps.

In an audio-based game with limited visuals, the sounds can possibly appear overwhelming if an excessively large amount is presented at the same time. If the player additionally concentrates on a singular sound, other sounds can fall into the background.

Furthermore, when participants encountered the sound of the enemies or the key object, which could be heard through walls, the participants most likely blocked out other sounds to instead focus all their concentration on the sounds representing the objectives. Whether participants did indeed block out the sound of the footsteps during gameplay, due to the presence of the enemy or key object requiring all their concentration, is difficult to measure. However, we can assume that based on their patterns of pursuing the enemy objects rather than the key objective, it is a likely argument.

A sound being overlooked is not necessarily a bad thing in games with visuals, where the sound appears as an aesthetical representation. However, as sound itself serves as a gameplay mechanic, it is crucial to consider how to ensure that the spatial sounds are registered by the participants.

However, it is important to consider that despite the majority of participants overhearing the footsteps, both participant A and participant H commented to have perceived the altering sound of footsteps, albeit participant A additionally remarked that they still experienced uncertainty regarding what direction they were navigating towards:

> Participant A:
>
> No. Again, I'm glad there were different sounds for the floor. That was a good help, but I still feel like there is direction problems, of like, where the sound of like going into a wall

> Participant H:
>
> Well, if there were four rooms and four different floorings, I think I only heard three. I could be wrong. (...) That was the cotton sound and if that was the carpet sound then that was one room but I actually didn't hear that one. (...) and then after the carpet there was this flat, like, walking on wood, and then it changed at some point to I would describe it like wood too but maybe a little deeper in sound. I think that was, that was three.

Whether this is in relation to the participants distinguishing the various sounds representing the terrain types is difficult to measure. This does oppose the presumption that the sound of footsteps was a necessity for the players to navigate, albeit it instead introduces the idea that the players did not need such a sound as a navigational tool, or perhaps it should merely appear in another format.

Participant F suggested an iteration wherein rather than the footsteps functioning as the singular navigational tool, room ambience relating to music could aid in differentiating between the rooms:

Participant F:

After you instructed me, I could tell the difference in the steps, but if you hadn't, it was confusing, because there was sounds of the steps and there was a new sound of bumping into the wall which is also steps. (...) I would just like that it would be sounds, like music, background music that would tell me I went into a different room, because the steps is hard to differentiate for me.

In a similar vein, participant G suggested that the navigational audio cues should merely be more distinguishable or louder in order to contrast the other sounds presented in the game world.

Participant G:

The difference of the floors, maybe turn that up a little bit, or make it more distinguishable, or something, (...) maybe a broader contrast between the floors, cause if you walk on sand and you walk on tiles, then you would immediately notice, ok, there's something changing here. But other than that, great. (...) I don't know, I feel like the contrast between walking from the mud and to the wood or sand to the wood was just to little, it was like, very hard to notice, I would want like a smack now you are walking on tiles or now you are walking on carpet.

Thereby, adding additional navigational audio cues in the format of subtle music or perhaps ensuring the footsteps were heard could draw the player's attention towards their current surroundings. Whether this indeed would improve their navigation, the observations cannot confirm, as most participants were able to navigate and complete the prototype game level without noticing the footsteps.

Further observations examining the participants' responses towards the presented soundscape revealed a likely necessity towards an introductory presentation of the game's sounds. Accordingly, participants could assimilate the sounds gradually in order to familiarize themselves with sounds and thereby understand what each sound signifies and how they should be interpreted (Garcia & de Almeida Neris, 2013). Other participants commented upon this as well:

> Participant D:
>
> Correct, without any intro of if you are hearing this sound, it is you hitting a wall. Here is the sound of an enemy, it was a little confusing at first, which is why I asked the question.

> Participant H:
>
> Yeah, with what happens with the mouse when you turn it, then yeah. I don't know if it would have been possible to catch onto it if you keep on trying and figuring on and okay if I don't touch that one and I only navigate. I don't know. I think personally it would have taken me a while to figure out. But I guess it could also be instead of the field where you actually play then you know a little test plane you know.

Such aspects of an additional tutorial at the beginning of the game level illustrate a potential towards enhancing navigation. By introducing a tutorial of the game mechanics as well as an introduction of each abstract sound, such as the sound for hitting a wall, it is likely to reduce risks of frustration, confusion, and participants forfeiting the game as they would be provided the knowledge on how to approach the game level and gameplay.

Whether such an introductory course on the various sounds present within the game would improve the participants' navigation through the level cannot be confirmed from the playtests. Nonetheless, findings on the effects of the footsteps as the sole audio cue for

navigation suggests that the sound was too subtle to be registered by the participants during gameplay.

Behavioral approach towards enemy objects

The documented data postulate a significant observation where rather than navigating the layout of the game by experimenting with the sounds of the level, participants appeared to navigate based on the spatial location of objects surrounding them, i.e. the sound of the enemies and the key object:

> Participant B:
>
> At first I thought it was someone walking around, like, with keys, but then I realized I knew from my time playing it earlier oh that's probably a new sound for the key so I started following it and I found it (...) Yes, the sound of a door was godsent, like oh ok, I found something. I found something.

> Participant H:
>
> Yeah, it was. It was actually if that drawing is correct then I would say it was right after I shot number two that I could start hearing this little rattling (...)

> Participant G:
>
> (...) because then it's like oh, something's happening. Oh okay, this is new and new is good, because that might mean key so the closer you get to the key, the more the sound is distorted or changed so maybe that's where the clinging sound comes from, or like, dropping a bundle of keys or a sharp THING.

Thereby, some of the participants adapted a reactive approach towards the gameplay, where rather than listening to the sound of the wall collision and the various sounds of footsteps and thereby map their location through this, players seemed to be guided through the level by sound of the enemies and the key as they would move between them (Grimshaw & Schott, 2007). It leaves no surprise that the participants would approach the sound signifying the key as that is the objective presented to them. However, some participants would appear more interested in the pursuit of the enemies and thereby ignore the key object altogether.

They therefore pursued enemies, using the enemies as a navigational guide, while also viewing the enemies as a secondary objective by actively attempting to defeat all of them. This is a significantly different behavioural pattern than the participants performed during the first prototype test session, wherein many of the participants were uncertain whether they had defeated any enemies:

> Participant B:
>
> Yeah, I think so. Because all of a sudden I couldn't hear anymore, so I assumed I had defeated all of them.

> Participant D:
>
> Yes, I think I killed one.

> Participant F:
>
> Yes, I did. I didn't even know it, but yes I did.

During the test session of the second prototype, the participants expressed confidence in defeating enemies as some of them additionally stated the amount they had defeated in their pursuit, hence illustrating that they were even counting the enemies.

> Participant B:

Yes.

Participant D:

Yes, three.

Participant F:

I got one, then three, and it was the best part of the game. More enemies.

As mentioned previously, the participants' behavioural approach towards the enemies also appear altered due to the iterated sound for representing the enemy objects. In the first prototype, the enemies were represented by an altered version of the player footsteps, wherein participants seemed to react towards the sound appearing louder when the enemy drew closer to them:

Participant E:

I heard that there was a new sound that slowly got louder so I just started firing, and then I hit it.

Interviewer:

And could you hear that you had defeated the enemy?

Participant E:

Yeah, because the sound disappeared.

However, the second test session used an iterated version of the enemy sound which was classified as a zombie groan, which consisted of a series of growls and moans. Results of

the iterated sound revealed that the participants were more emotionally invested in the new sounds, assigning characteristics of horror and suspense onto them:

Participant B:

They sounded like zombies and terrifying.

Participant D:

I could tell they were hostile. I giggled, because it sounds very much like minecraft enemies (...) so hearing that was cool because I immediately then related to the sound and knew that they were enemies and whenever they got closer it was more suspenseful because they changed their audio when they were coming close.

Participant H:

Yeah, they were breathing. They were annoying. It was kind of creepy to hear them breathe and you can't see them. That makes me want to chase them.

Due to the iterated sound representing the enemies, the participants altered their approach towards the game as well, as many of the participants commented that they actively pursued the enemies. Assumptions were initially made regarding participants listening for the key rather than attempting to defeat the enemies, although many participants did the opposite:

Participant F:

I was. In the first game, not the second one. The first game, I got one bad guy and the key right away and in the second one I got all three bad guys but I could not find the key.

Participant D:

Yes, because I found it in the first room I went, and then was trying to avoid it to fight the other enemies.

Participant G:

Yes, I feel like it was pretty easy actually. Because it was the same way you guys made the key sound. The like, getting closer and getting further away and stuff, so I felt like it was pretty easy actually, fairly easy actually. (...) No, no, no, because there were two enemies that I couldn't find. I could hear them and I kind of chased them.

Furthermore, as the game prototype was introduced as an FPS to the participants upon presentation, the participants could have made assumptions regarding whether the intention of the game was to defeat the enemies as well. Generally, the participants likely experienced more enjoyment with the additional challenge of defeating enemies:

Participant G:

I think that would make the game more fun, like more long-lasting fun, like, it would give it like a motive other than just find the key. Because the first thought I had about the enemies were like, don't go near them, they will kill me, that was just my first- I had anticipated that because that's how it always is in games, right?

Interviewer:

Was it more fun to go for the enemies as an objective and then go for the key.

Participant H:

Yeah, I think so.

These findings support the argument that some of the participants likely sought an additional challenge in the game e.g. participant D commented that they heard the key object in the first room, but actively avoided it as they wanted to defeat all the enemies. This possibly presents the reasoning for why the participants explored and completed the game level.

If it had been introduced as a survival horror or if the participants had not been assigned a weapon with the intention of defeating enemies, they might have actively avoided the enemies and instead concentrated on finding the key. Additional comments by participants seem to provide another reasoning for why they were more likely to pursue the enemies than search for the key as the participants thought the key was being carried by one of the enemies.

Participant A:

(...) I really liked the sound of the key and it actually made me feel like it was an enemy that had the key and I had to follow them even if that wasn't what it was, it felt like it.

Participant H:

Actually I didn't think about it. I thought, I guess I said that before too, I have this picture of this monster walking around with this huge key chain and then that was what I heard, but when the third one died, and the keys were still around, I kind of knew well oh it wasn't the monster then and then I don't know coincidence I just went left and it was there

These comments evidently suggest that even if the participants did not seek additional challenges, due to their assumptions of the represented sound, their approach and perception of it changes. Despite the key object remaining a stationary object throughout the

level, the participants associated the sound of jingling keys with the idea of a moving opponent, which was only made more apparent with the additional growls of enemies. As such, the results additionally support documented literature wherein interpretation of sound arises from personal perceptions as well as current environment which can shape interpretations towards sound (Chion 1994; Liljedahl, 2011; Garner T., 2013; Summers, 2016). Moreover, the sound representing the key object and the sound representing enemies were immediately understood by the participants. Thereby, they were identified as sound signals of direct relation as the participants did not need to learn the sound beforehand and understood the significance immediately (Jørgensen, 2007).

In the prototype, the footsteps and the sound representing the doors were presented as 2D sounds in Unity, meaning that they appeared as the original channel mapping which does not consider the distance or direction of the player. Contrarily, the enemies were presented as 3D sounds, wherein the sound channel was annotated according to the distance and direction to the sound object. Therefore, the results support documentation arguing for binaural 3D sounds enabling and enhancing player navigation as the participants seemed more engaged towards the more reverberating sounds (Bălan, Moldoveanu, Moldoveanu, & Dascălu, 2014). Evidently, the footsteps themselves only provide knowledge of the terrain participants walk on rather than the size or shape of the room and remain constant, while the sound of the enemies provide the spatial directional information participants can utilize to navigate.

Player engagement

The results presented above support the fact that the participants experienced engagement with the prototype due to their pursuit of additional challenges. As presented in the theoretical chapter of this paper, player engagement appears from a state of flow where the challenges and the skill level of the player are balanced, thereby ensuring the challenges presented are neither too difficult nor too easy (Csikszentmihalyi, 2008).

The observations illustrate a tendency wherein participants were likely to become unaware of their temporal surroundings as they played the game. This becomes apparent as participants would continue to play the game until the interviewer would notify them that a specified amount of time had passed and therefore inquire whether they wanted to continue the game or forfeit. The interviewer interrupting the participant could disengage the

participant from their state of flow, where the participants then explained they lacked the appropriate level of skill to hear where the key object was located.

The findings provide a possible argument for a learning curve present wherein the game appears difficult for the participants at the beginning, while the participants evidently explained that the gameplay became easier once they understood what each of the sounds signified:

> Participant D:
>
> Yeah, for sure. But once I knew that, I could kind of go around the room and be like ok, if I am hitting a wall here then I need to go this way. This is a door opening, so I am close to the door.

> Participant F:
>
> Not in the beginning. In the beginning it was like. Well steps are easy to connect to a sound like dig dig dig dig but then there was a different sound and I had to figure out that, like, what I called hitting a wall meant I had to back off and turn right or left. It took a while to figure out that it was what it was. And then you told me I could shoot so I just shot every time I felt like I hit a wall. So in the beginning that is what was to me, I had to like find a space where I could walk freely, if I couldn't walk freely and I hit a wall, I would shoot.

The documented findings thereby support the argument that in order to contain the player within the flow-zone to encourage engagement within an audio-based game, the difficulty of the game must appear to complement the player's abilities of navigation. Some sounds were easily registerable by the participants such as shooting a gun or hearing the door open, which in turn were easily familiarized and the participants could instead concern themselves with the sounds that proved unfamiliar such as walking against a wall.

The results obtained further suggest that the task of finding the key or defeating the enemies engaged the participants in the task. When the participants lost sense of where the key object was located, they felt less inclined to continue, as the interviewer informed them of how long they had attempted to locate the key object. Comparatively, the participants who were able to consistently hear the location of the enemies or the key continued to be in a state of engagement as the objective was close by. As the participants continuously were in a state of player engagement, they persistently attempted to navigate through the game level:

> Participant G:
>
> I don't know, I felt like the last ten minutes I just walked around and there was no enemies and every time I heard like an enemy, I just walked toward them and shot it. Cause that made fun- that gave like the game a meaning, you know, something to do which was fun.

Based on the participants' behavior and perception of the enemies, it is difficult to confirm why they were engaged with the additional challenge of pursuing them. Whether this is due to player type behavior such as the participants' who frequently play FPS games might be more engaged in chasing the enemies, or it could possibly be due to the interest of exploring the level. Previous comments regarding player perception of the enemies carrying the key can also suggest a reasoning behind their engagement. It therefore appears that each participant held a separate reason for their continued engagement with the prototype.

Summary

Based on the results obtained from experiments wherein sighted participants navigated through an audio-based world with limited graphics, a series of significant patterns arose from how participants interacted with the virtual world. The findings provide a significant argument towards the value of sound used as a navigational tool for participants, as most participants were able to complete the task of finding the key objective, while several of the participants sought a secondary challenge in the enemies found around the game level. This further suggests a heightened sense of engagement from the participants as they continued

to interact with the game. While the data shows a faster completion time of the first prototype, several factors including participant playertype and game mechanic misunderstandings could have led to those results. However, these results can only construct presumptions towards the participant navigation and player engagement with the prototype, as the participants inhabited varied behavioral patterns in their playthroughs.

What could we have done better?

During the design and testing of this project there were a few things that we believe we could have done better as some things were not as thoroughly discussed among the group members as they could have been.

One thing that could have been done better were the test settings during the test sessions. We had not discussed in detail how we were going to test each person and as we were conducting the tests on our own without other group members present, we ended up doing our test sessions differently from the other members. This resulted in some members asking more and perhaps deeper questions than others and some members talking or helping the test participants more. Some members also tested with a different setup and perhaps got better insight in their test participants' navigation than we got from other participants.

This is not to say that getting these results was bad, however, if we had, as a group, agreed upon the same way of testing all participants, we could have gotten the same kind of insight from all participants and not only a select few. In comparison, some of the tests seemed slightly lackluster and might not have given us all the insight that we needed for the project. Additionally, there was a mix of offline testing and online testing due to not being able to always test in the same room because of COVID-19. Before the test sessions, we had mostly discussed the settings surrounding the online test sessions but each group member did offline tests as well. We will discuss if online or offline testing worked better for us later in this section.

Another thing that we could have done better was to perhaps have a deeper look into 3D sound. As we used Unity there was already a level of 3D sound as we made sure to change the settings. However, we still had a few test participants who were confused about the location of enemies once they got closer to them. This could have been corrected if we had spent more time looking into how 3D sound works in Unity. There are many suggestions on how to make it better on the Internet and had we spent more time testing the sounds and

tweaking them, we believe that everything could have been a bit less confusing for our test participants.

Online versus offline testing

As mentioned previously there was a mix of offline and online testing in our test sessions. This was mainly due to COVID-19 as the restrictions did not make it possible for us to always test in the same room with our participants. However, there were a mix of preferences to what was the better option in the group. Some group members preferred to test online whereas others preferred offline testing.

The offline test setup had not been discussed in detail within the group and so each member did it in their own way, which we assume is why the preferences between online and offline are mixed. One test member did their offline testing by having the test participant play the game inside of Unity. With two monitors she was able to have the participant look at a screenshot from the game that showed everything they would have seen had they played the actual prototype while she herself could monitor Unity. This meant that she could see the participant's movements and get a much deeper insight into their navigation. However, as this was done a bit later in the test sessions, other group members had not done the same thing and had struggled a bit with how to test participants in an offline setting. There was some struggle with how to record everything and where they as the interviewer should place themselves during the playthrough so that they would not disturb the participant too much. Another struggle was that in an offline setting, since all participants tested with a headset, it was not possible for the interviewer to hear the game. Not being able to hear the sounds when the participants heard them made it difficult to answer any questions about the sounds they were hearing and thus the interviewer had to explain what the sound would sound like and possibly disrupt the flow of the gameplay for the participant.

Further improvements

If we were to work more on this game there would definitely be a great amount of improvements that could be made. Our initial vision for the game was far greater than a prototype called for and thus we would go back and revisit these ideas to see what would still fit in and what would not.

The initial idea was to make a shooter with three different gun types, which the player would be able to purchase from a vending machine. Furthermore, it would resemble a typical shooter a lot more by having gun reloads, ammunition, health, and a melee attack.

Another thing we would be looking into is the enemies' behavior. We wanted enemies to follow the player and attack them, thus giving the player more motivation to shoot the enemies as the attack would deplete the player's health and there would be a way to lose by dying. All of this was not put into the prototype as for what we were trying to figure out, it was not necessary and would have perhaps been too much for the participants. However, if we had tested more we would have added more of these elements as the testing progressed.

Additionally, if we were to go further with testing and develop the game more we would have to look more into the sounds. The sounds currently used are all recorded and found sounds and therefore not our own and subject to copyright. Furthermore, they are not entirely depicting the feeling and atmosphere that we wanted. Therefore, we would look more into developing our own sounds through means like foley and digital sound design. This obviously takes some skill that we would have to improve, hence why we did not do this for the prototype.

One thing that was discussed a lot during the making of the second prototype was how we wanted the different rooms to be distinguished from each other. We ended up doing this through different footstep sounds. However, there were test participants that mentioned to perhaps do this in another way as they, themselves, did not notice footsteps very much but would have noticed the rooms changing if there had been different ambient sound in each room. There were several other test participants who also did not notice the change in footsteps or got confused as to when they happened but they did not mention any way of improving this for them. What we would do to improve this has as of writing this not been discussed but we would probably do it through different means like improving the footsteps, adding some ambient sound as well as adding various elements to the rooms that each have their own sound. This would have to be done in a way that would not be too overwhelming for the player as too many sounds might just add confusion but that is another thing we would have to discuss within the group and test further.

If we were to make this game into a fully developed, published game, we discussed making it into a sort of dungeon crawler with various levels that would each have its' unique layout. Additionally, we would introduce a variety of different enemies, each enemy being added one by one to let the player learn the enemies' sounds before introducing more to them.

Conclusion

This project aimed to explore the possibilities of engagement and navigation within audio-based computer games. We wanted to present a concept of a computer game with limited graphics and which predominantly used audio cues to guide the players through a virtual environment. Taking inspiration from a variety of games across a diverse range of genres, we constructed a simplified prototype of an audio-based game using game mechanics similarly found in first-person shooter genres. Through a theoretical framework consisting of Jørgensen's identification of sound (2007) and the theory of flow by Csikszentmihalyi (2008), sounds were selected based on familiarity and a prototype was constructed where the game mechanics were simple enough to master, although still ensured that the player stayed in a state of flow. Participants were gathered through convenience sampling to test two seperate prototypes, wherein the secondary was an iterated version of the first prototype, exploring a more complex soundscape of navigational audio cues. Through quantitative and qualitative data we discovered that it is important to balance the volume levels of all sounds so the important sounds are never drowned out e.g. in the first prototype the key had a very faint sound, which led to players not noticing it. Additionally, volume levels can affect people in different ways if they are not used to hearing particular sounds and/or they are sensitive to sound e.g. we found that some participants did not like the sound of the gun whereas others liked it, which we assume is due to some of the participants being used to shooters and other were not.

We had assumptions that different types of footsteps would help the participants navigate through the level easier but most of the participants did not seem to pay any attention to them. This could be due to the participants being used to this sound from other games or that it did not in fact help them to listen to these sound cues. Furthermore, we found that most participants listened for more reverberating sounds of the enemies as this sound seemed more engaging, however, we are not sure what exactly made this sound so engaging. We assume that it was due to the enemies presenting an alternative goal for the participants and as some people like to explore and complete everything within a game, this caught their interest.

Based on the amount of participants who completed the second prototype, we can assume that the audio cue aided them in navigating the simplified game level. However, we cannot confirm whether if the game level had been larger or if it had been in a different setting, it would have yielded different results. This therefore opens the opportunities for further research into audio cues as a navigational aid.

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