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THE EVOLUTION OF VIDEO GAME ACCESSIBILITY FOR PEOPLE WITH MOTOR IMPAIRMENTS

A Case Study of Accessibility in The Last of Us series

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ABSTRACT

Markus Kämäräinen: The Evolution of Video Game Accessibility for People with Motor Impairments – A Case Study of Accessibility in The Last of Us series
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My thesis seeks to produce knowledge on the evolution of video game accessibility for players with motor impairments. The research aims to analyse the state of accessibility in The Last of Us games. Additionally, it assesses the games' ability to maintain pleasurable accessible player experiences. The goal is to indicate how accessibility has evolved between The Last of Us games. Formal analysis was used for gathering and sorting data. Furthermore, the analyses of the games' mechanics, interactions, accessibility barriers, and accessibility solutions were conducted by several frameworks. In addition, both games' pleasurable accessible player experiences were analysed separately. Lastly, the results were collected into a table and compared to determine the evolution of accessibility between The Last of Us games. The general state and different approaches to video game accessibility as well as previous research were disclosed via literature review.

The results indicate that the status of accessibility has evolved from inaccessible The Last of Us to accessible The Last of Us Part II. The researched sequence in The Last of Us possesses multiple accessibility barriers that cannot be surpassed, whereas The Last of Us Part II has plenty of accessibility solutions to overcome most of the encountered barriers. Furthermore, the analysis suggests that the sequel greatly supports pleasurable accessible player experiences, while the first game does not.

The analysis implies that most of the accessibility barriers come from quick-time-events and inadequate input requirements. Other issues are caused by timed events, enemy behavior, and high precision requirements. The Last of Us Part II responds to the barriers by offering multiple alternative input methods, automatized or reduced interaction strategies, and highly customizable gameplay.

Keywords: Accessibility, Video game accessibility, Motor impairments, Disabilities, Video games, Mainstream games

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1 INTRODUCTION

The accessibility of digital media has become more common in recent years as virtual environments are experiencing similar changes towards accessibility as physical environments have been in the past two decades. This is especially notable on the internet and web services, which benefitted from the EU's web accessibility directive in 2016 (Directive 2016/2102), but the phenomenon is also reaching the video game domain. In the past couple of years, video game studios have started to adopt accessibility solutions into their games either at launch or later via downloadable game patches. A crucial factor for this development has been major accessibility advocate organizations such as *AbleGamers* and *Can I Play That*, along with vocal players in social media, who have brought the issues in video game accessibility to broader attention. However, as video game accessibility is a contemporary development, there is a significant lack of academic study and measurement models.

There is no precise estimation of how many players with disabilities or otherwise in need of accessibility solutions globally exist. However, there are at least 46.3 million potential players with various disabilities in the United States alone (Cairns et al., 2019b). Furthermore, the need for accessible games is only rising as current players grow old. Even when new games from big studios could possess only the bare minimum of accessibility settings, an apparent change is occurring in the culture of considering accessible design. Still, there is relatively little academic research on what kind of evolution has happened in the technical level, let alone in a mainstream game context. My thesis seeks to analyse the progression regarding video game accessibility by comparing two games from Naughty Dog: *The Last of Us* (2013) and its sequel *The Last of Us Part II* (2020).

I chose The Last of Us games for three reasons. Firstly, it is reasonable to compare games from the same studio since there could be a vast difference in accessibility solutions among studios. Secondly, the selected games belong in the same system (PlayStation) and are rather similar mechanic-wise; both are linear, third-person action-adventure games that contain stealth, firefights, collectible items, and interacting with the UI (user interface). Lastly, the seven-year gap between the games' launches should give an excellent indication of possibly evolved accessibility.

My thesis is essentially a case study that aims to assess in detail the evolution of video game accessibility of the past decade by analysing and comparing The Last of Us series, mainly focusing on people with motor impairments. Thus, I do not consider players with blindness or low-vision, deafness or hard of hearing, neuropsychiatric disorders, or cognitive impairments. The reasoning for this is both practical and the lack of studies concentrated purely on motor impairments in the mainstream game context. Moreover, my thesis illustrates the effectiveness of combined accessibility evaluation and measurement methods to assess the accessibility of deconstructed game mechanics in a detailed level. Finally, I seek to determine the effect and evolution of accessibility solutions' ability to maintain pleasurable player experiences.

2 BACKGROUND

In this chapter, I will further elaborate on the definitions of video game accessibility and motor impairments, overview briefly previous research on video game accessibility, and present a basic sorting for distinct approaches of video game accessibility. Video game accessibility in all its broadness is a rather unknown topic; therefore, unfolding the phenomena feels necessary.

2.1 Video game accessibility

On a general level, accessibility is the design of products, services, and environments to be accessible by everyone, regardless of their abilities. Although accessibility and accessible design is usually connected for benefitting people with disabilities, it has long been beneficial for non-disabled people as well, for example, in telecommunications and application designs for mobile phones (Henry et al., 2014). The most cited and utilized WCAG (Web Content Accessibility Guidelines) states four principles for web accessibility: *perceivable*, information and UI must be able to be perceived; *operable*, UI must be operable; *understandable*, information and UI must be understandable; *robust*, content must be robust enough that it is possible to interpret reliably by different users (W3C WAI, 2018). These principles are also adopted either partly or entirely in video game accessibility guidelines and frameworks.

Video games are an ever-growing industry. As stated in the International Data Corporation, the video game industry revenue is expected to surge $179.7 billion in 2020, making it bigger than the global movie and North American sports industries combined (Witkowski, 2020). Games are entertainment, hobby, passion, and profession for many, and people with disabilities are no exception. In fact, I argue that games are even more crucial to people with disabilities since, on some occasions, games can enable one of the few activities that a particular person with a disability can even practice. As Miesenberger et al. (2008) argue, "it is about [enabling individuals with disabilities to take] part in a societal phenomenon of growing importance" (p. 253). Further, stated in the research of Cairns et al. (2019a), the enabling aspect of games is vital for people with disabilities as games give them equality, inclusivity, and autonomy. Through virtual worlds, players with disabilities are in equal positions among non-disabled players – provided that the accessibility of the game is sufficient.

In video game domain, the accessibility often refers to different solutions and options to player encountered *accessibility barriers*. Yuan et al. (2011) determine two types of accessibility barriers: *critical*, which prevents the gameplay altogether; and *non-critical*, which does not prevent the gameplay but can lessen the game experience for players with disabilities. Essentially contemporary game accessibility methods are just problem-solving where players with varying needs appear as problems that can be fixed via different options. Yet, it is indeed the game design that creates the barriers; through more accessible design from the early phases of game development, games could be profoundly inclusive. Simple games are relatively easy to craft to be entertaining and accessible from the beginning, such as one-switch minigames (Lopez et al., 2015). However, in more complex games, it is considered easier to add accessibility options rather than considering accessibility from the ground up. In some cases, the tacked-on accessibility options modifying existing games can hold significant trade-offs as the original gameplay and gaming experience intended by the designers are critically altered in the way that they are not fun to play any longer (Yuan et al., 2011). Furthermore, different game accessibility guidelines are often utilized to evaluate and find accessibility barriers and "quick wins" that transform games accessible (Cairns et al., 2019b). Guidelines and checklists can be an effective method for evaluating and reassuring games' accessible nature. However, according to Cairns et al. (2019b), they might not aid when games fail to meet the guidelines and guidelines cannot assess desired player experiences. If game mechanics or puzzles are automated or made painfully obvious, is it any more an interactive game, or an entertaining one at least?

One rather common misconception among people is thinking that games' adjustable difficulty and accessibility are essentially the same thing or tied closely together – they simply are not. According to Hoogen et al. (2008), the difficulty of a game correlates with players' arousal levels and sensations such as frustration, boredom, flow, and competence. Players can customize their desired play experiences with adjustable difficulty – some prefer easy, and others demand hard difficulty. Accessibility is about enabling the play experience altogether with the best possible methods. They share similarities but are fundamentally different.

2.2 Research on video game accessibility

In the past ten years, there have been multiple academic studies regarding video game accessibility, yet they consider mainly a specific type of impairment in a particular game instance or seek to develop new experimental accessible games (Cairns et al., 2019a). Instead of experimental game projects, my thesis is interested in the accessibility of mainstream games designed for the general public's entertainment. Mainstream games represent the valued aspects of playing and connecting with each other (Cairns et al., 2019a), and as such, they should be a priority to be made accessible. According to Porter et al. (2013), the majority of research has focused on developing design recommendations for game developers relying on laboratory studies and high-level modelling of impairments. Fortes et al. (2017) conclude in their literature review on accessibility evaluation methods that most works have utilized either user-based evaluation methods not focused on a game domain or inspection methods focused on games. So far, visual and motor impairments have dominated the topics in accessibility studies. For example, there have been studies on specific games for people with visual impairments, such as *Blind Hero* (Yuan et al., 2008) and *VI-Tennis* (Morelli et al., 2010), as well as different models for assessing games and barriers for people with visual impairments (Salvador-Ullauri et al., 2020). However, there is a lack of accessibility studies in a mainstream game context. Furthermore, there are little to no retrospective inspections or studies on the evolution of video game accessibility.

2.3 Approaches to accessibility solutions

There are at least four approaches to game accessibility. People with motor impairments wield a vast array of assistive technologies – what I call *hardware-based accessibility solutions* – to overcome games' accessibility barriers. These include, for example, mouth-operated controllers like *QuadStick*, customizable switch-controller hub *Xbox Adaptive Controller*, a bodily gesture device *Kinect*, brain-wave controllers, and eye-operated controllers (Gómez et al., 2014; Poor et al., 2011; Smith et al., 2016). Nintendo's *Hands Free Controller*, a mouth-operated controller launched in 1989, is the earliest commercially released assistive device for players with disabilities. When combining assistive technologies with certain software, players with disabilities can script and customize the executable inputs to suit their needs. Hardware-based solutions are often relatively unique and highly adapted to a particular player's needs, making them an effective solution. However, the situation is far from ideal as hardware are costly, require major technological capabilities, and players must often craft different scripts for every new game. Moreover, alternative hardware does not have the same capabilities as a regular game controller, consequently limiting the range of games players can play when using alternative hardware (Yuan et al., 2011).

Usually, together with hardware-based solutions are *software-based accessibility solutions*. These solutions consist of different programs that can be utilized to control games, e.g., via voice commands, customizing accessibility hardware as mentioned before via software such as *QuadStick Manager Program*, or as a complementary method for gaining broader access to game inputs such as *Dragon Naturally Speaking* software's speech commands to supplement manual inputs (Sporka et al., 2006).

Modern game consoles and systems possess basic accessibility options applicable in all games inside the system, such as button remapping. With the contents of the 2.50 patch in PlayStation 4 back in 2015, Sony was the first major gaming system to introduce a broad set of accessibility options in the system. These so-called *system-based accessibility solutions* can benefit players with disabilities, but they rarely remove barriers completely as, for instance considering motor impairments, they do not include interaction method customizations that are often crucial.

Finally, there are games' own accessibility options – what I call *game-based accessibility solutions* – unique game-based solutions to aid players in playing the game without restrictions. Generally speaking, games' accessibility options are usually by far the most effective solutions regarding player control and maintaining the pleasure of the game experience. Solutions can be anything from changing how the enemy reacts to making players invincible. In my thesis, I specifically examine and compare game-based accessibility solutions of the selected games.

2.4 Motor impairments

Motor impairments and motor disabilities are vast umbrella terms that mean function limitations in muscle control or movement, or a limitation in mobility. Usual causes include arthritis, paralysis, cerebral palsy, lost limb, Parkinson's disease, or repetitive strain injury. (Yuan et al., 2011.) Furthermore, natural aging may cause a loss of motor functions.

Players with motor impairments have limitations on providing physical inputs in regular game controllers or mouse and keyboard. Even if they have functional fine motor skills, hands and fingers can quickly fatigue or become strained if a game has a lot of repeated inputs or button holds. In many cases, players with motor impairments must use alternative input devices – hardware-based solutions – which possess limited capabilities. Therefore, game actions that require precision, multiple simultaneous inputs, or time limitations can be difficult or impossible for players with motor impairments. (Yuan et al., 2011.) For example, if a game requires players to aim by constantly pushing the L2 button and simultaneously shoot by pressing the R2 button, it makes the seemingly simple interaction impossible for mouth-operated controllers since one cannot constantly blow into one tube and puff into the second tube at the same time. Unless, the game has a toggle option – a game-based solution – that changes the constant pushing of the L2 button to pushing the button to aim and pushing again to stop aiming.

In summary, if a game requires players to hold buttons, press them repeatedly in a quick manner, push multiple buttons simultaneously, be precise, or act fast – without any alternative methods – it very likely induces accessibility barriers for players with motor impairments.

3 THEORETICAL FRAMEWORK

In this chapter, I present the theories for focusing on motor impairments, evaluating the gameplay tasks, and assessing the desired player experiences. I must utilize different frameworks for different aspects of the research because currently there is no single model that could evaluate the accessibility in its entirety.

3.1 Strategy to focus on motor impairments

Video games are interactive media, which significantly differs from other mediums. In a technical perspective, this means that video games provide output and feedback adapting to players' executed inputs. As Yuan et al. (2011) establish the game interactivity in the *Game Interaction Model*, video game interaction has three steps. 1.) Games generate stimuli in three forms: visual, auditory, and haptic. 2.) Based on the stimuli, players make a conscious decision for a response. 3.) *Players provide the input*. The game interaction is often built on an ability assumption of a player. The assumption considers players having a sight, hearing, and motoric ability to be able to receive the stimuli and execute the correct input. Unfortunately, the assumption excludes partly, or in extreme cases completely, many people with varying disabilities from playing games. In the Game Interaction Model, the third step concerns people with motor impairments, which is relevant to my thesis. Players with motor impairments can receive the stimuli and decide the correct response yet providing the required input can generate challenges (Yuan et al., 2011).

The required input devices can be divided into *discrete inputs*, where a device supports discrete inputs, such as an on-off switch, and *analog inputs*, where a device supports continuous input, such as a controller analog sticks input. Analog inputs require a more precise movement – which can pose challenges for people with motor impairments – but they allow a broader range of inputs. General game controllers support both input methods in the form of buttons and analog sticks. Furthermore, Yuan et al. (2011) concluded different strategies that accessible games utilized: *reduction*, the original interaction is removed either partly or completely; *automation*, the original interaction is automated either partly or completely; *scanning*, the correct interaction selection utilizes scanning. Scanning puts available interactions into a chain and runs through the chain until the user decides the correct interaction (Yuan et al., 2011). One of my accessibility assessments is how the selected games handle these input methods and strategies.

3.2 Examining the gameplay interactions and accessibility solutions

My thesis employs the *Unified Design* model of games from Grammenos et al. (2007) to assess the accessibility of singular game mechanics of Naughty Dog games. The model aids to disassemble the games' interactions and analyse their suitability for players with disabilities. For example, by utilizing Unified Design, it can be seen that the requirement for aiming in The Last of Us games is a constant holding of the L2 button, which could be a critical accessibility barrier for motor impairments. Unified Design consists of five steps that are used to analyse and devise alternatives to mechanics. The analysis in my thesis considers the first two of these in a motor impairment perspective. The steps are:

1. **Abstract task-based game design**. The aim is to deconstruct the high-level tasks performed by players when playing a game.
2. **Polymorphic specialization with design alternatives**. The previous tasks are mapped to low-level, physical alternative interactive designs, meeting target players' attributes.

3.3 The assessment of accessibility solutions' effect on player experience

Cairns et al. (2019b) propose a broad range of vocabulary of game accessibility that no longer issues whether someone can perceive or play a game, but instead as to whether players can have the play experience they want. Hence, they developed the *APX triangle* (Figure 1) from the research of Power et al. (2018) that defines the necessary steps for having *pleasurable accessible player experiences* (APX). My thesis utilizes the APX triangle to assess how the games' accessibility settings maintain pleasurable gaming experiences. APX triangle has three levels: access, challenge, and accessible player experience.

Figure 1. APX triangle in Cairns et al. (2019b). In order to meet the requirement for accessible player experiences (APX), firstly access and secondly challenge level requirements must be accomplished.

According to the research of Cairns et al. (2019b), access and challenge levels possess multiple options that help to determine games' suitability for delivering the pleasurable accessible experience. The top-level, APX, does not include any options but acts as a goal that is achieved by fulfilling the access and challenge levels.

In the access level, the model considers players' access to the game through its interfaces by the following options:

- **Input Options**: These allow players to customize their used controller(s). Players with motor impairments often need to play games with a customized controller which transfer, for instance, button press from PlayStation 5's DualSense controller to blowing a tube in QuadStick controller.

- **Control Options**: These allow players to remap buttons, add new controls, and adjust the reaction of the game and its UI to the controls. Furthermore, it includes adding macroinstructions (transfer series of inputs into a sequence of output) or other interfaces to reduce button presses. They are crucial as motor impairments highly vary, so button schemes that are suitable for one can be utterly useless to others.

- **Presentation Options**: These allow players to customize the information that is presented to the player. This includes choosing the amount of perceptible information mediated to the player such as sudden flashes or variable audio channels and customizations of the user interface contents. Presentation options do not directly affect motor impairments as they are not concerned about interactable contents or inputs. Therefore, I do not include them in the analysis.

- **Output Options**: These allow players to choose the output devices, for example, large TV screens or mobile phone screens. Similar to the presentation options, output options do not directly influence or aid motor impairments, so I do not include them.

Once players successfully fulfil the access level, the APX model assesses the game's challenge in relation to the player's abilities and disabilities by the following options:

- **Performance Options**: These allow the customization of reactions players would need to have in the game. For example, slowing down the game, providing alternatives to pause or queue up actions, or changing or removing the game's timers are performance options that alter game mechanics. Players with motor impairments can have limited input methods or reaction times, making games significantly more challenging for them, if there are no methods for altering the games' performance.

- **Training Options**: These include training levels, tutorials, and just-in-time help through cues or overlays. Training levels, tutorials, and hints are important for players to adopt a particular game's mechanics and interactions and players with motor impairments are no exception. In fact, they could greatly benefit from training options as they need to test customized controllers and button schemes.

- **Progress Options**: These allow players to continue to progress in the game when encountering obstacles that are too challenging or uncomfortable. Retaining progress or objects they have achieved, return previous points in the game, or bypass challenging sections are examples of progress options. Furthermore, tips and hints, auto pass detection, and tracking of objectives also belong here, as they aid players to progress. These are vital as by having progress options, players with motor impairments can skip sequences that have so severe accessibility barriers that they prevent progression.

- **Social Options**: These allow players to customize the ways they collaborate with other players. This includes modifying the game's social contents, such as game chat or looting rules, and do not concern about input or output methods by which players communicate. Social options bear no relevance to my thesis as The Last of Us games are mainly single-player experiences.

- **Moderation Options**: These allow players to customize the emotional challenges in the game content, for example, via trigger warnings, adjustable gore, or sexual content settings. These do not directly relate to motor impairments and, as such, are not included in my thesis.

4 METHODOLOGY

In this chapter, I will present my research questions, further illustrate how I wield the different frameworks to find the answers to research questions, explain the reason for choosing The Last of Us series, and disclose my own position as a researcher with motor impairment.

4.1 Research questions

My thesis seeks to find answers to two video game accessibility-related research questions. The questions are:

1. How has the accessibility evolved between the two The Last of Us games?
2. How the possible accessibility solutions maintain the pleasurable player experiences?

4.2 Research methods

For the basis of the data gathering and analysis method, I utilized the methodology and vocabulary of *formal analysis of gameplay* presented by Lankoski and Björk (2015). The formal analysis aims to describe the formal features of a particular work, which in games are the systemic features such as game elements, rules, and goals. In my thesis, my interest is in game elements and mechanics that are either explicitly or implicitly connected to accessibility.

I used the formal analysis for the general gameplay data gathering method to deconstruct the gameplay sequences of The Last of Us games into parts. This means the distinction of different *primitives* of a predetermined game state: *components*, *agents*, and *goals*, and most importantly *player*, *component*, and *system actions*. Additionally, I distinct the required discrete and analog inputs of the gameplay sequences as they are the primary aspect that determines the accessibility possibilities for players with motor impairments.

After I played through and deconstructed the gameplay sequences, I used the Unified Design Model for mapping the gameplay tasks and elements to physical alternative interactive designs to determine A) their original suitability for players with motor impairments, and B) possible different game-based accessibility solutions when original interaction acted as an accessibility barrier.

Then, I compared the original interactions' suitability and game-based accessibility solutions to assess their differences and evolution from the first game to the sequel. Lastly, I analysed the game-based accessibility solutions per APX triangle to evaluate their effect on maintaining pleasurable accessible player experiences.

4.3 Research data

The analysed game series, The Last of Us and The Last of Us Part II, is one of the most well-known and critically acclaimed console franchises, and there is a seven-year gap between the games' launches. Therefore, it was the perfect candidate for evaluating the evolution of accessibility in the mainstream game context. Even though the narrative and some game mechanics differ, the core game mechanics and gameplay-loop are essentially identical. The Last of Us series and the action-adventure genre, in general, is a sensible choice for accessibility evaluation not just because of the popularity, but they often include high-pace action sequences, timed events, platforming, puzzles, and different types of environment manipulation. These transform the gameplay into diverse and changing, which can pose significant accessibility barriers if not appropriately designed or lack effective alternatives.

The Last of Us Part II is a ground-breaking example of how to properly address accessibility in games as it has around 60 different accessibility options. According to the article of Webster (2020), when Naughty Dog started developing the game, they received a message from a player who had their gameplay stopped during another Naughty Dog's game *Uncharted 2: Among Thieves* (2009) due to quick-time-event requiring rapid button pressing. This prompted them to make The Last of Us Part II accessible at the beginning of the development cycle allowing them to craft such adjustments and options that would have been practically impossible to implement later.

The analysed gameplay sequence of The Last of Us was 'Hotel Lobby' level in the Pittsburgh chapter. In the level, I played as Joel who had a companion, Ellie. In The Last of Us Part II, I analysed the level 'The Tunnels' in Seattle Day 1 chapter. In that level, I played as Ellie and I had a companion, Dina, with me. Both games' researched levels had human and infected enemies, environment manipulation, traversal methods, and game state interactions. Depending on the playstyle, it took roughly 30 minutes to one hour to complete the levels in question.

For the analysis, I classified the game interactions into four categories: obligatory plot progression interactions, movement and traversal, interactions with items and game state, and combat. I also utilized these categories when presenting findings. The categorization clarifies data analysing and later presentation by separating different circumstances in which interactions occur. All of the categories are obligatory to some degree for the game progression, but their manifestation frequency is dependent on the environment, player's play style, and enemy components and actions. If the game is played by sneaking around and strangling enemies or going head-on to firefights, it affects which interaction categories are mainly used.

I collected the data by having multiple playthroughs of the sequences with different playstyles and difficulty settings to acquire a thorough understanding of the required play strategies and game mechanics. Also, I took notes during and after the play sessions. For the playing itself, I used PlayStation 5 console with its most recent firmware patch (21.01-03.00.00). Furthermore, while playing The Last of Us I quickly realized that I had to utilize the button remapping in PlayStation 5's system-based accessibility solutions.

Most importantly, I must disclose my own position as a person with a motor impairment, which affects both playing and analysing the games. I am a quadriplegic person in a wheelchair without any function in my fingers and limited activity in my hands. This is crucial for two factors. Firstly, I cannot play games with the regular game controller due to my motor impairment. Hence, I must use a combination of hardware-based and software-based accessibility solutions. In my case, a mouth-operated controller hardware – QuadStick – with a regular joystick combined with QuadStick Manager Program software that allows high-level scripting and customization of the QuadStick controller. Secondly, because I have a motor impairment and must use assistive technologies, different accessibility solutions are a necessity rather than a choice. Thus, I pose valuable first-hand insight on game accessibility for players with motor impairments, and I utilize my experiences and expertise when analysing the games. However, motor impairments and disabilities vary considerably, so I cannot have expertise about all of the different needs and requirements, nor do I even intend to place myself into that position. Instead, I wield my subjective experiences as a player belonging to the focus group to conduct objective research on the subject.

5 RESULTS

In this chapter, I will present the research findings in detail. Firstly, I will explain the potential accessibility barriers and possible game-based solutions in The Last of Us games. Then, I will present the games' capability to maintain pleasurable accessible player experiences. Lastly, I will demonstrate a table that compares the research results.

5.1 Accessibility in The Last of Us

5.1.1 Obligatory plot progression interactions

The researched sequence had four obligatory plot progression interactions that posed possible critical accessibility barriers. All of the barriers were simple quick-time-events; three required quickly repeated button presses to open the jammed door (Figure 2) or release the player from a deadly grab, and one required timed button presses to pull the lever in order to start the generator. Pulling the lever was not time-restricted – as long as the player pulled the lever in the right time slot three times, the generator would start. Furthermore, there was an obligatory sequence where Joel must dive through the tunnels to progress the level. Joel had an oxygen variable; therefore, the player must dive and swim rather quickly to avoid drowning and resetting the game situation. This can be a critical accessibility barrier as well.

Figure 2. The player must press the triangle button repeatedly in a quick manner to progress to the next level in The Last of Us.

5.1.2 Movement and traversal

Movement and looking are executed by analog inputs using left and right analog sticks that can be swapped. They follow the very basics of a game design so players with motor impairments or assistive devices can adopt these effortlessly. However, running requires constantly pushing the L1 button, which is a significant accessibility barrier depending on the current game state. If the player explores around without an imminent threat, running acts as faster transportation between spaces; hence, not being able to utilize it is a nuisance but not a critical barrier. However, in combat situations, running can be crucial for escaping the battle or sprinting to cover, so in these cases, the prevention of its use is a critical accessibility barrier as it often leads to a player's death. Similarly, the Listen Mode mechanic that allows tracking enemies through walls also requires constant pushing of the R1 button, potentially excluding players with motor impairments from using it.

5.1.3 Interactions with items and game state

In The Last of Us, some interactions require either long button presses or other inaccessible input methods. For example, crafting items or a medical kit that heals Joel requires holding the X button, and applying it happens by holding the R2 button. Furthermore, particular game state manipulations are performed by holding the triangle button. Moreover, the game's flashlight mechanic is an extreme example of inadequate and inaccessible design. Based on either time or a game situation, the flashlight begins flickering, which makes it distracting and simply useless in dark environments. The only way to fix the flashlight is to shake the game controller up and down rapidly – a task that is impossible to execute with assistive devices or with some motor impairments.

5.1.4 Combat

The combat in The Last of Us raises the most significant accessibility barriers for players with motor impairments. First of all, the game requires players to press the L2 button continuously to aim the gun or throwable objects and shoot or throw by pressing the R2 button – shooting is not possible without aiming. Hence, players who cannot continuously press a button and execute multiple inputs simultaneously cannot shoot enemies, reducing or entirely preventing the play experience. Furthermore, if some enemy types get close to Joel, they grab him causing continuous damage until the player breaks free by rapidly pressing the square button quick-time-event. Additionally, when the player is fist-fighting enemies, sometimes a brief triangle icon pops up to indicate an incoming attack from the enemy. Successfully pressing the button within the time limit prevents the attack; failing to execute damages Joel. The time window of the prompt is rather short, possibly making it problematic for players with motor impairments. Melee combat itself is performed by repeatedly pressing the square button in which a single button press executes one punch. The enemies require multiple punches before taken down so the constant button pressing may cause fatigue or strain.

5.1.5 Accessible experience in The Last of Us

Control Options are scarce since the player could only swap the controls between analog sticks and L1/R1 and L2/R2. Thus, The Last of Us does not fulfil even the access layer of the APX triangle, essentially meaning that it would be theoretically irrelevant to evaluate the game's challenge layer. Additionally, the game includes camera inversions and sensitivity options that allow some adjustments for aiming.

Performance Options of the game are only related to difficulty setting. For instance, there is an aim assist in which the crosshair automatically seeks and locks on to enemies when aiming the gun. However, the feature is only restricted to Easy difficulty, whereupon it cannot be activated in more challenging difficulties. It is a questionable, yet usual, restriction as players with motor impairments could desire a challenging experience aside from aiming – and the game does not allow that. Furthermore, enemy reactions and interactions could only be modified via the game's difficulty settings, which is a rather vague method to adjust the performance.

Training Options appear in the forms of a tutorial level in the beginning of the game, strategy tips in the menu and loading screen, and situational game tips when the player seems to be stuck in a game sequence. Additionally, the button prompts in situational quick-time-events appear distinctly, although they also are restricted to easier difficulties.

Progress Options in The Last of Us are only available in the checkpoint system and puzzle hints. Checkpoints allow the player to restart the game situation relatively close to the point where they have failed or died. Puzzle hints give clues about how a particular puzzle can be solved. Still, there is no means to skip sequences that are challenging or completely prevent the progression.

5.2 Accessibility in The Last of Us Part II

5.2.1 Obligatory plot progression interactions

Similar to its predecessor, the obligatory interactions in The Last of Us Part II also included opening jammed doors, releasing Ellie from the enemy grab, and starting the generator. Yet, the quick-time-events could utilize reduction or automation accessibility strategies by three methods: they did not require quickly repeated button presses but holding a single button instead; the repeated button sequence was not time-limited so the player could press the button at their phase; the seemingly time-limited repeated button sequence was not obligatory to succeed as even if the player did not press the required button a single time, the sequence would succeed thanks to Dina's aid. Furthermore, in the game's accessibility options the repeated button presses could be changed to be executed via holding the button. However, the generator minigame was more challenging in The Last of Us Part II as pulling the lever was time-limited. If the player waited too long between the pulls, the generator minigame would reset. Additionally, there were no game-based accessibility solutions to overcome the minigame; hence, it is a critical accessibility barrier since in some cases it may prevent the progression.

There is also a time-limited running sequence in the end of the researched chapter where Ellie must escape the infected through metro tunnels. The sequence must be executed rather perfectly in a very limited time slot for Ellie to be able to escape – failing to do it results in death and returning to a checkpoint. Fortunately, the escape scene is split into three checkpoints, which makes the experience more accessible as Ellie does not reset to the beginning of the escape if gets caught by an infected. Furthermore, there is a Traversal Assistance accessibility setting that uses the automation strategy by making Ellie automatically sprint in the encounter, easing the workload and button presses of the encounter. Besides, with easier difficulty, the enemies that normally instantly kill Ellie, grab her instead allowing more room for errors – although grabbing causes the aforementioned quick-time-event. Regardless of the game-based solutions, I interpret the scene as a non-critical barrier as it may cause significant trial and error before succeeding for players with motor impairments, ultimately reducing the play experience.

5.2.2 Movement and traversal

Movement and looking are executed by analog inputs by the left and right analog sticks. They can be swapped similarly to The Last of Us. Sprinting happens by holding the L1 button, but the interaction can utilize automation strategy by switching the constant holding to briefly hold to sprint and briefly hold to stop sprinting via the game's accessibility options. Additionally, Listen Mode executes by holding the R1 button, but it also can be changed to briefly hold through the accessibility options.

The Last of Us Part II introduces a new rope mechanic in which Ellie can throw ropes over ledges, climb, swing, and jump from them to progress and reach new areas. Throwing the rope happens by holding the L2 button to aim and pushing the R2 to throw. These can be switched to toggles in the accessibility options. The R1 button must be held to swing the rope and it cannot be changed to toggle – the X button commands Ellie to jump from the rope. Fortunately, the player can either make Ellie automatically jump from the rope using automation strategy via Traversal Assistance or skip the rope sequence entirely utilizing reduction strategy via the Skip Puzzles accessibility option.

5.2.3 Interactions with items and game state

In The Last of Us Part II, the player can craft items by holding the X button either in the weapon wheel or backpack menu. These can be automated to toggles in the game's accessibility options. Yet, applying a medical kit executes by holding the R2 button, of which interaction cannot be changed. Additionally, some game state progressions, such as going through a jammed door, are achieved by holding the triangle button that cannot be modified. Furthermore, The Last of Us Part II possesses the same issue with fixing the flashlight flickering as its predecessor, meaning that the controller must be shaken to fix the flashlight. Although the button can seemingly be switched from shaking the controller to something else, the remapping menu will not allow the player to complete the change. All interactions must be mapped and if the player changes the flashlight fix executable by, for example, pressing the L3 button, which originally is the Look At command, then the Look At must be bound to something else – and, for some unknown reason, it cannot be switched to directional pad or shaking the controller (Figure 3). Hence, there are no available buttons so the shaking cannot be changed to something else; and controller shaking is impossible to execute with assistive devices or with a particular motor impairment.

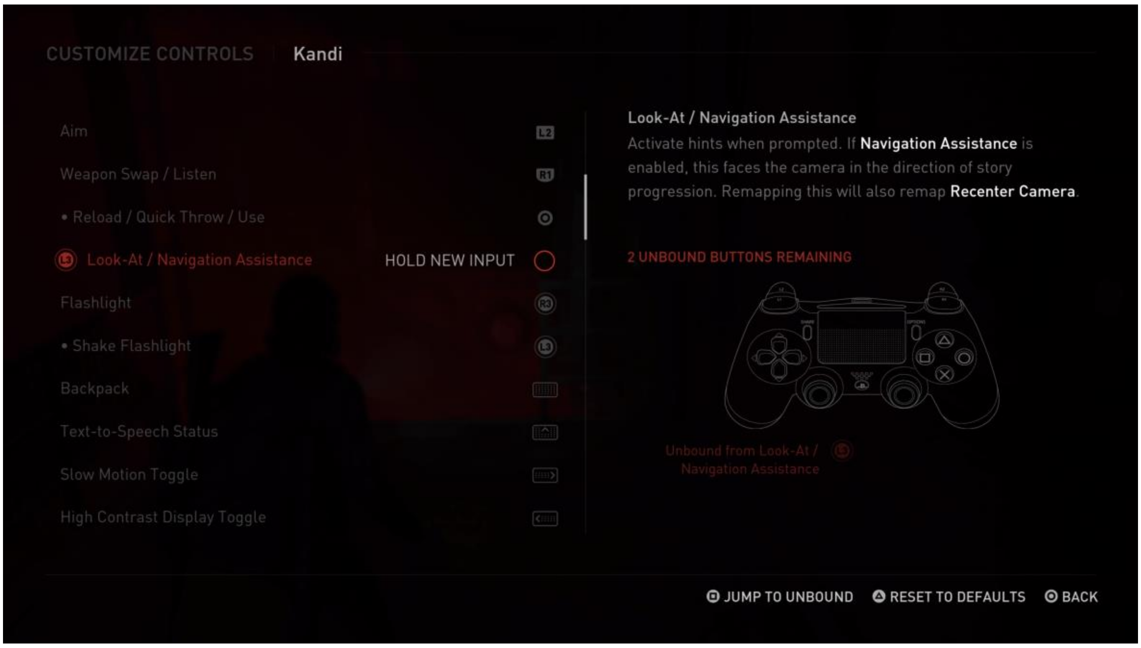

Figure 3. The button remapping will not allow other input methods for unbound button than shaking the controller, and it will not let the player close the remapping menu with unbound buttons.

5.2.4 Combat

Aiming the gun or throwable objects executes by holding the L2 button and shooting or throwing by pressing the R2 button. Fortunately, the holding to aim can be automated to toggle in the accessibility options, meaning that pressing the L2 button aims the gun and pressing again stops aiming. Furthermore, some enemy types could grab Ellie if they get close to her prompting a quick-time-event where the square button must be quickly pressed multiple times to release Ellie. The repeated button press can be changed to holding the button in the accessibility options. Moreover, melee combat is performed by repeatedly pressing the square button in which a single press executes one knife stab. The interaction can be switched to holding the button so as long as the player holds the square, Ellie will stab and swing her knife.

5.2.5 Accessible experience in The Last of Us Part II

Control Options in The Last of Us Part II are near perfect. Essentially all of the buttons, aside from analog sticks and controller shake, can be switched increasing considerably the player’s options and overall accessibility. Furthermore, there are distinct sensitivity settings for looking and aiming, camera inversions, as well as aiming acceleration and ramp power scale. Additionally, the orientation of the controller can be utilized to adjust the aim direction making aiming easier and more refined. There is even Camera Assist that utilizes the reduction strategy by orienting the camera based on where Ellie is moving, which is vital for players who have difficulties operating both analog sticks simultaneously. The Last of Us Part II also has a vast amount of alternative input methods as, for example, most button holding requirements can be changed to toggles and repeated button presses can be switched to holding the button. Lastly, the game has plenty of ways to reduce interactions and input requirements such as automatic weapon-swap and item pick-ups, the possibility to melee while aiming, and multiple automated jumping and climbing interactions.

Performance Options continue the excellent accessibility solutions in The Last of Us Part II. It has multiple difficulty options that automatically adjust the game experience, but players also can customize all the difficulty variables: Player, Enemies, Allies, Stealth, and Resources (Figure 4). Besides, the game does not reduce the accessibility options when played on harder difficulties as the predecessor does. Furthermore, there are highly customizable lock-on options for aiming and throwing and a possibility for time slow-down when aiming the gun. Lastly, there are eight additional methods for altering the encounter mechanics such as reduce enemy accuracy, enhance Ellie's dodge, or enemies cannot intentionally flank players.

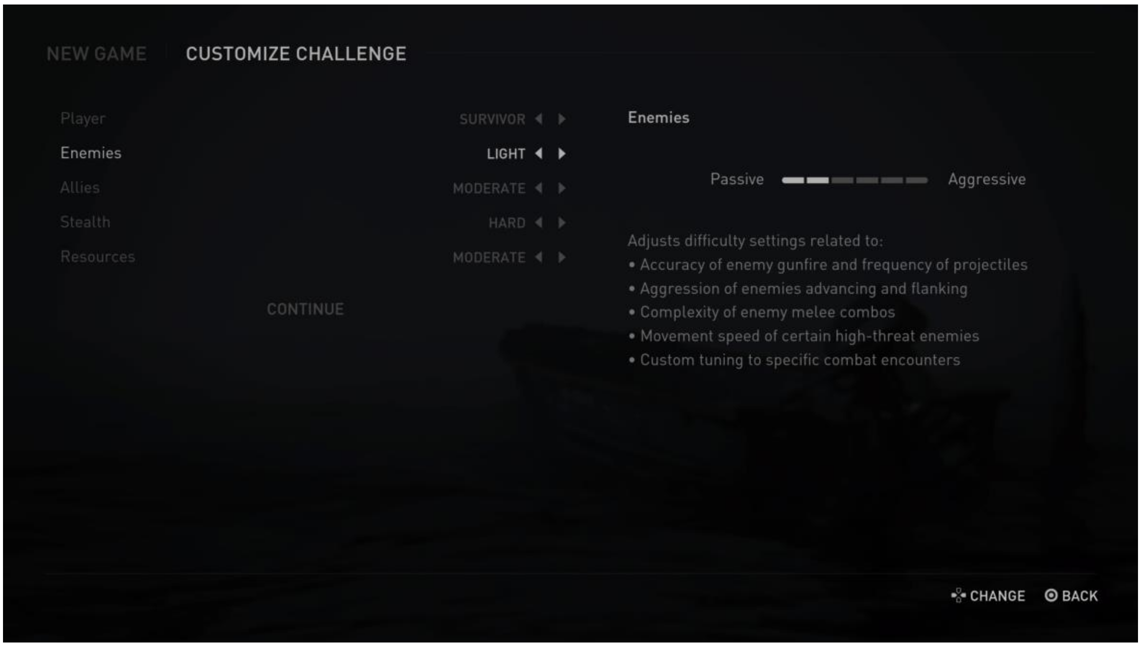

Figure 4. The detailed difficulty customizations in The Last of Us Part II.

Training Options include the tutorial level in the beginning of the game, tips and hints during the gameplay and loading screens, and navigation assistance in accessibility options. In addition, different HUD (heads-up display) elements and prompts for dodging, grabbing, picking up items, and interactions can be turned on and off and they are not restricted by difficulty except some elements and prompts in the hardest difficulty.

Progress Options in The Last of Us Part II possess a similar checkpoint system as the first game, but the checkpoint frequency can be altered. Furthermore, it is possible to wield reduction strategies by skipping all of the puzzles that otherwise could prevent the progression. Additionally, the game has an infinite breath option so that the oxygen variable will not put pressure on players. Traversal Assistance enables automatic sprinting in running encounters and the ledge guard prevents Ellie from being killed by falling off the ledge. Also, Ellie can be turned invisible while prone in the accessibility options allowing her to crawl through challenging encounters without the fear of enemies spotting her.

5.3 Comparison between accessibility barriers and solutions

Based on the findings, Table 1 summarises the types and severities of accessibility barriers in The Last of Us games as well as possible game-based accessibility solutions. As Table 1 and data analysis imply, The Last of Us games share plenty of similarities in interactions, contents, and accessibility barriers. However, there is an apparent difference in game-based accessibility solutions of the games. The Last of Us includes only a few solutions that are, in some cases, locked to easier difficulties, whereas the sequel has almost always a solution to an accessibility barrier available in all difficulty settings aside from minor restrictions in the hardest difficulty.

Additionally, it is noteworthy that the obligatory quick-time-events in The Last of Us Part II were developed to be accessible and, in some cases, automatically succeed even if the player fails to execute the button prompts, whereas, in the first game, similar events could hamper or completely prevent the gameplay. That indicates the clear difference in the design philosophy of the games as the sequel is developed accessible by design – a feature that was probably unknown during the development of The Last of Us. Yet, it is worthy of consideration if The Last of Us Part II should have removed the quick-time-events altogether. Why even have a feature that could pose accessibility risks if it is ultimately made to automatically succeed.

Table 1. The encountered accessibility barriers and their possible solutions in the analyzed games.

	The Last of Us			The Last of Us Part II		
Accessibility barrier	Critical barrier	Non-critical barrier	Game-based solution	Critical barrier	Non-critical barrier	Game-based solution
Situational Quick-Time-Event	**X**		No		**X**	Yes
Obligatory Quick-Time-Event	**X**		No	**X**		No
Button hold requirement	**X**		No	**X**		Yes
Simultaneous inputs	**X**		No	**X**		Yes
Timed event	**X**		No		**X**	Yes
Non-skippable section	**X**		No	**X**		No
High precision	**X**		Difficulty dependent	**X**		Yes
Button mappings		**X**	Scarce		**X**	Yes
Enemy behavior		**X**	Difficulty dependent		**X**	Yes

6 DISCUSSION

The results were abundant but, in the end, a rather clear and greatly answered to research questions. In the following paragraphs, I will present the answers to the research questions.

1. How has the accessibility evolved between the two The Last of Us games?

Even though neither The Last of Us games were thoroughly accessible, the evolution of accessibility between the two games is obvious. In the first game, I had to utilize a combination of highly customized hardware-, software-, and system-based solutions for being able to complete the researched sequence, whereas, in the sequel, I could finish the researched level with basic hardware- and game-based solutions. This is vital as games cannot obligate players to understand high-level technical skills for being able to enjoy the said game. Furthermore, The Last of Us included a plethora of accessibility barriers both critical and non-critical yet it did not have virtually any game-based solutions to overcome the barriers (Table 1). Accessibility barriers were inflicted by input and high precision requirements, timed events, quick-time-events, and enemy behaviour. Some of the barriers could completely prevent the progression while others could hinder the enjoyability and play experience. The Last of Us Part II had similar barriers but, in most cases, it had one or multiple game-based accessibility solutions to rectify the initial barrier. Therefore, The Last of Us series has evolved from the inaccessible first instalment to the accessible sequel – for players with motor impairments at least.

2. How the possible accessibility solutions maintain the pleasurable player experiences?

As for the games' ability to enable pleasurable accessible play experience, neither access nor challenge level fulfilled in The Last of Us indicating that the game fails to achieve pleasurable accessible experience. Essentially all sections in both levels have fundamental issues regarding players with motor impairments, hence reducing or preventing the play experience. On the contrary, The Last of Us Part II greatly succeeds in reaching the APX triangle's options and enabling the pleasurable accessible experience by having multiple accessibility adjustments and novel solutions. Aside from the barriers mentioned earlier regarding the flashlight shake and the generator mini-game, the game allows players with motor impairments to have a broadly customizable, highly accessible, and pleasurable play experience. Thus, also the pleasurable accessible experiences evolved from scarce The Last of Us to the great variety and possibilities of The Last of Us Part II.

The results have important aspects to consider. First of all, the difference in accessibility between the two games is remarkable. The first game contains many elements making it inaccessible and downright unplayable for players with motor impairments. As games, and specifically mainstream games, offer new experiences, launch the player beyond their homes, provide reasons to connect (Power et al., 2018), and enables players autonomy and social connections (Cairns et al., 2019a), the barriers in The Last of Us thwart all of these. The inaccessibility of the game is not a rare exception but a common situation – a norm even – in mainstream games. The approach for designing specific games for players with disabilities does not help the situation but eliminates the players from social connections. It puts the players with disabilities in a "disability ghetto" removing them from cherished aspects of games. (Cairns et al., 2019a.) Fortunately, The Last of Us Part II alleviates the deficiencies of the predecessor by offering a highly accessible and enjoyable game experience – a rare feat for a widely recognized mainstream game. Thus, Naughty Dog and The Last of Us Part II should act as a prime example for other game studios of how to properly perform the inclusive design.

The prominent accessibility evolution between the two games should courage other developers for crafting accessible and inclusive games since The Last of Us games are essentially identical in everything but accessibility. Therefore, their vast difference solely in accessibility implies that many other mainstream games could be made highly accessible if developers put time and thought into them. According to the blog post of Sony Interactive Entertainment, Naughty Dog succeeded because they thought accessible and inclusive design from the very beginning and brought accessibility experts and players along to the development ("Naughty Dog Blazes the Trail for Accessible Storytelling", 2020). The results suggest this being a highly effective method.

The few accessibility solutions in The Last of Us are locked behind the difficulty setting. It is a relatively usual habit in games. For instance, Horizon Zero Dawn (Guerilla Games, 2017) and Gears 5 (The Coalition, 2019) lock the aim assist for easier difficulties. Brown and Anderson (2020) keep adjustable difficulty a valuable resource for players with disabilities. Yet, I find the discourse of difficulty and accessibility being similar or closely tied together rather worrisome. As I noted before, difficulty and accessibility are fundamentally different, and they should be kept that way. Usually, difficulty settings inevitably alter multiple predefined variables in the game, hence they create an illusion of potential accessibility. Accessibility is far more than a health and damage variable or enemies' awareness range, as it comprises a vast amount of input and output methods, interactions, and gameplay mechanics. Thus, a mere difficulty setting cannot encompass accessibility at its complexity. Furthermore, locking accessibility for easier difficulties forces players with disabilities to play a lighter experience, even though many of them could desire the challenge. Players with disabilities can possess high strategic skills, fast thinking, and a great sense of rhythm but cannot, for example, aim accurately due to their disability or impairment. Hence, being locked to easier difficulties could expose them to boredom (Hoogen et al., 2008). The results indicate The Last of Us Part II excelling in both of these cases – it allows highly customizable challenges, and it does not lock accessibility behind easier difficulties.

Many of the accessibility solutions in The Last of Us Part II utilized reduction or automation strategies defined by Yuan et al. (2011). This implies that the strategies effectively grasp the issue regarding motor impairments and propose functional solutions. The Last of Us Part II launched ten years after Yuan et al.'s (2011) paper, which could indicate three things: the strategies for motor impairments are effective enough that they are widely adopted ten years later, the transformation from research to praxis has been slow, or there is a significant lack of further research on accessibility and strategies for motor impairments. Considering the scarce academic research on video game accessibility in general, I suggest that the latter argument is closest to the truth. Strategies identified by Yuan et al. (2011) are helpful, but they could be refined further as, for example, some interactions in The Last of Us games were not reduced nor automated but *replaced* by other interaction methods or the games' accessibility settings *added* completely new interactions that are not initially in the game. Therefore, replacing and adding interactions should be identified as additional strategies in further studies. Lastly, the scanning strategy was not utilized at all, although I find it challenging to adopt in action-heavy games like The Last of Us series. However, scanning could be highly potential in turn-based games.

Generally, it is always risky to draw too strong conclusions when evaluating any kind of desired user or player experiences through frameworks or checklists as people's skill levels, experiences, and preferences vary considerably. Grouping the users and players to simple demographics can lessen the validity of the results. According to McCarthy and

Wright (2004), by simplifying individuals in the design process, the conglomeration of moral, political, and emotional experiences of individuals in that system are lost. Power et al. (2018) also urge the importance of considering the players' lived experiences, goals, and expectations in the design – a task that cannot be predicted or ensured by property checklists. As such, even the APX triangle model, first suggested by Power et al. (2018) and later refined by Cairns et al. (2019b), that is meant to address the pleasurable accessible experience, essentially is a checklist itself; thus, posing the very challenges that it seeks to alleviate. From the research perspective, the only method to undoubtedly ensure the validity of pleasurable accessible player experiences is to conduct proper user research with the players with impairments or disabilities. At least, there should be an extensive database about previous play experiences of players with impairments or disabilities that the researchers and designers could utilize.

Finally, since accessibility solutions vary greatly, my distinction between different approaches to accessibility proved effective. For example, some players must use a combination of all hardware-, software-, system-, and game-based solutions whereas others need to utilize only the latter. Therefore, we need a vocabulary that clearly distinguishes the solutions from another as it would aid both research and design of the novel accessibility options. In my thesis, the separation of the solutions significantly clarified the data gathering and analysis.

7 CONCLUSION

My thesis aimed to assess the evolution of accessibility between The Last of Us games and analyze their capability of maintaining pleasurable accessible player experiences. Based on the research, it can be concluded that the accessibility has significantly evolved from the first game to the sequel. The Last of Us includes multiple accessibility barriers but does not offer any solutions to overcome those, whereas The Last of Us Part II contains similar barriers yet in most cases has one or many accessibility solutions to correct the obstacles. Still, even when the sequel is currently the prime example of how to properly address accessibility in a video game, there appear few accessibility barriers that the game cannot rectify. Furthermore, The Last of Us Part II greatly supports pleasurable accessible play experiences, whereas The Last of Us possess major issues.

It is important to remind that the data gathering and analysis were challenging, which could affect the results. Even though The Last of Us games are linear experiences, they contain a myriad of components and variables between the obligatory goals of the games. These components and variables make each playthrough a unique experience, which complicates gaining a coherent picture of the games. As such, gaining a thorough understanding required multiple meticulous playthroughs and varying play strategies. I utilized Lankoski's & Björk's (2015) definition for validity and reliability in which they urge plentiful description of the gameplay, transparency about the researcher's backgrounds and biases, having multiple playthroughs, and persistent checking of used categories and descriptions. Furthermore, I had to take into account the varying accessibility in each game state instance. In addition, I needed to consider the possible effects of a particular difficulty setting on the available accessibility. For that, I played the researched game sequences in each difficulty mode.

I found successful combining the frameworks or models of Yuan et al. (2011), Grammenos et al. (2007), and Cairns et al. (2019b) for evaluating game accessibility for people with motor impairments. All of the models proved to be effective and offered promising results. However, the Unified Design by Grammenos et al. (2007) seemed to overlap with the formal analysis but it was still a valuable addition to my thesis. Furthermore, the APX triangle was functional for assessing pleasurable accessible experiences, yet the descriptions of the model felt too vague. Thus, it allowed plenty of space for interpretations but, at the same time, it increased the risk for errors or misinterpretations. Considering everything, both the data gathering and analysis were a success, but they have room for errors. Hence, there is an apparent need for effective, solid, and reliable models to evaluate video game accessibility in all its broadness.

Future research could refine existing or develop new frameworks for accessibility evaluation, especially in assessing accessible player experiences and interaction strategies. Furthermore, more academic research on accessibility in a mainstream game context is highly essential. Contemporary games are growing more accessible hence they could possess valuable information for refining or crafting frameworks. Additionally, we need closer co-operation between the academic and professional research on accessibility. Currently, the separation between the two is a significant missed opportunity since recent professional research and appliances on video game accessibility have made great strides. Yet, professional research on accessibility tend to hold major business interests, hence the research and results may be kept in private. Still, academic research could greatly benefit from the user research data and proven practical applications in the professional context and correspondingly academic research could offer frameworks and methods for accessibility assessment as well as solidify the importance of accessibility via encompassing player research. Lastly, there should be dedicated research on the fundamental differences between the difficulty and accessibility.

My thesis acted as one example of how to conduct an academic accessibility evaluation and comparison with the given models. It is vital that whenever the accessibility of a game is evaluated, the game must be played and analyzed meticulously. No matter how broad the accessibility settings seem to be, they must be tested in practice. Furthermore, as the models were largely unproven, the thesis tested the models' reliability – and they mostly actualized. In addition, my thesis provides a rough vocabulary to distinguish different accessibility solutions from each other. Lastly, my thesis suggests that mainstream video games could be a fruitful basis for further academic accessibility evaluations due to their unique interactions and complex structures. After all, the accessibility in video games is still rather immature but recently begun trending and the results for that are apparent in late video games.

REFERENCES

Brown, M., & Anderson, S. L. (2020). Designing for Disability: Evaluating the State of Accessibility Design in Video Games. *Games and Culture*. https://doi.org/10.1177/1555412020971500

Cairns, P., Power, C., Barlet, M., Haynes, G., Kaufman, C., & Beeston, J. (2019a). Enabled players: The value of accessible digital games. *Games and Culture, 16*(2), 262-282. doi:10.1177/1555412019893877

Cairns, P., Power, C., Barlet, M., & Haynes, G. (2019b). Future design of accessibility in games: A design vocabulary. *International Journal of Human-Computer Studies*, *131*, 64-71. https://doi.org/10.1016/j.ijhcs.2019.06.010

Directive 2016/2102 The accessibility of the websites and mobile applications of public sector bodies. European Parliament and of the Council of 26 October 2016. http://data.europa.eu/eli/dir/2016/2102/oj

Fortes, R. P. M., de Lima Salgado, A., de Souza Santos, F., Agostini do Amaral, L., & Nogueira da Silva, Elias Adriano. (2017). Game accessibility evaluation methods: A literature survey. *Universal Access in Human–Computer Interaction. Design and Development Approaches And Methods,* 182-192. https://doi.org/10.1007/978-3-319-58706-6_15

Gears 5. (2019). (Xbox One) [Video game]. Vancouver, CA. Xbox Game Studios.

Gómez, I. M., Molina, A. J., Cabrera, R., Valenzuela, D., & Garrido, M. (2014). The possibilities of kinect as an access device for people with cerebral palsy. *Computers Helping People with Special Needs*, 252-255. https://doi.org/10.1007/978-3-319-08599-9_38

Grammenos, D., Savidis, A., & Stephanidis, C. (2007). Unified design of universally accessible games. *Universal Access in Human-Computer Interaction. Applications And Services*, 607-616. https://doi.org/10.1007/978-3-540-73283-9_67

Henry, S. L., Abou-Zahra, S., & Brewer, J. (2014). The role of accessibility in a universal web. *Proceedings of the 11th Web for All Conference (W4A '14). Association for Computing Machinery*, New York, NY, USA, Article 17, 1–4. https://doi.org/10.1145/2596695.2596719

Hoogen, W., Ijsselsteijn, W., & De Kort, Y. (2008). Exploring behavioral expressions of player experience in digital games. *Proceedings of the Workshop on Facial and Bodily Expression for Control and Adaptation of Games ECAG 2008.*

https://www.researchgate.net/publication/242468669_Exploring_behavioral_expressions_of_player_experience_in_digital_games

Horizon Zero Dawn. (2017). (PlayStation 4) [Video game]. Amsterdam, NL. Sony Interactive Entertainment.

Lankoski, P., & Björk, S. (2015). Formal analysis of gameplay. *Game research methods: An overview*. (pp. 23-35). Pittsburgh, PA: ETC Press.

Lopez, A. S., Corno, F., & De Russis, L. (2015). Can we make dynamic, accessible and fun one-switch video games? *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility*, Lisbon, Portugal. 421–422. doi:10.1145/2700648.2811333

McCarthy, J., & Wright, P. (2004). *Technology as experience*. Cambridge, Mass: The MIT Press.

Miesenberger, K., Ossmann, R., Archambault, D., Searle, G., & Holzinger, A. (2008). More than just a game: Accessibility in computer games. *HCI and Usability for Education and Work.* doi:10.1007/978-3-540-89350-9_18

Morelli, T., Foley, J., Columna, L., Lieberman, L., & Folmer, E. (2010). VI-tennis: A vibrotactile/audio exergame for players who are visually impaired. *Proceedings of the Fifth International Conference on the Foundations of Digital Games,* Monterey, California. 147–154. doi:10.1145/1822348.1822368

Naughty Dog Blazes the Trail for Accessible Storytelling. (2020). https://www.sie.com/en/blog/naughty-dog-blazes-the-trail-for-accessible-storytelling/

Poor, G. M., Leventhal, L. M., Kelley, S., Ringenberg, J., & Jaffee, S. D. (2011). Thought cubes: Exploring the use of an inexpensive brain-computer interface on a mental rotation task. *The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility,* Dundee, Scotland, UK. 291–292. doi:10.1145/2049536.2049612

Porter, J. R., & Kientz, J. A. (2013). An empirical study of issues and barriers to mainstream video game accessibility. *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility,* Bellevue, Washington. doi:10.1145/2513383.2513444

Power, C., Cairns, P. & Barlet, M. (2018). Inclusion in the third wave: Access to experience. *New Directions in Third Wave Human-Computer Interaction: Volume 1 – Technologies.* (pp. 163-181) doi:10.1007/978-3-319-73356-2_10

Salvador-Ullauri, L., Acosta-Vargas, P., Gonzalez, M., & Luján-Mora, S. (2020). A Heuristic Method for Evaluating Accessibility in Web-Based Serious Games for Users with Low Vision. *Applied Sciences (2076-3417)*, *10*(24), 8803. https://doi.org/10.3390/app10248803

Smith, J. D., & Graham, T. C. (2006). Use of eye movements for video game control. *Proceedings of the 2006 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology - ACE '06*. doi:10.1145/1178823.1178847

Sporka, A. J., Kurniawan, S. H., Mahmud, M., & Slavik, P. (2006). Non-speech input and speech recognition for real-time control of computer games. *Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility,* Portland, Oregon, USA. 213–220. doi:10.1145/1168987.1169023

W3C WAI. (2018). Web Content Accessibility Guidelines (WCAG) Overview. Retrieved from https://www.w3.org/WAI/standards-guidelines/wcag/

Webster, A. (2020, June 1). Naughty Dog explains The Last of Us Part II's ambitious accessibility features. The Verge. Retrieved from https://www.theverge.com/21274923/the-last-of-us-part-2-accessibility-features-naughty-dog-interview-ps4

Witkowski, W. (2020, December 22). Videogames are a bigger industry than movies and North American sports combined, thanks to the pandemic. Retrieved from https://www.marketwatch.com/story/videogames-are-a-bigger-industry-than-sports-and-movies-combined-thanks-to-the-pandemic-11608654990

Yuan, B., & Folmer, E. (2008). Blind hero: Enabling guitar hero for the visually impaired. *Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility,* Halifax, Nova Scotia, Canada. 169–176. doi:10.1145/1414471.1414503

Yuan, B., Folmer, E., & Harris, F. C. (2011). Game accessibility: A survey. *Universal Access in the Information Society*, 10(1), 81-100. https://doi.org/10.1007/s10209-010-0189-5