Edge Hill University

Evaluation and Development of Accessibility Features Within Video Games

CIS3140 CW2 – Project Report

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Abstract

Accessibility within video games has seen improvements in recent years, however, issues still exist within the industry that does not allow for equal access for impaired players. Previous research from over seven years ago found the same issues that remain today. The situation is that the current state of accessibility within video games is not good enough. Therefore, this project aims to highlight the current issues surrounding the need for equal access and provide the preliminary data required to introduce certain accessibility features.

Research is gathered from the specific laws and regulations surrounding accessibility for video games. Guidelines such as the Game Accessibility Guidelines (GAG) try to encourage and promote the issues mentioned. A puzzle game has been identified to use as a case study for the implementation of accessibility features. The ideas that GAG try to promote will be implemented and analysed using survey data. This data is collected from participants in the hopes that the aims and objectives of the project are met.

Keywords: Accessibility, equal access, video games, guidelines, research, survey, case study, laws, regulations

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Lastly, I would like to thank all participants who took part in both the pre-test survey and the amended survey. The data collected played a critical part in the evaluation of both the project aim and the conclusion of this project.

Chapter 1: Introduction

1.1. Background and Motivation

The project analyses and highlights an issue within the video game industry regarding accessibility features. The project tries to provide the preliminary data required to solve this issue, resulting in improved equal access for the industry. Standards and guidelines for accessibility features must exist and be recognised within the industry. This has already been addressed for websites with the introduction of the Disability Discrimination Act 1995, which has since been repealed and replaced with the Equality Act 2010. Laws and regulations like this would help promote and encourage companies to incorporate guidelines such as the Game Accessibility Guidelines (GAG) within their games. The GAG aims to promote and encourage this idea. These guidelines help support and cater to gamers with disabilities by identifying what accessibility features need to be implemented within video games (Game Accessibility Guidelines, 2022).

A puzzle game has been identified to use as a case study for the implementation of accessibility features. The puzzle game will demonstrate the ideas that GAG tries to promote within the industry by implementing accessibility guidelines within the game. The following report will examine and analyse all the work that has been implemented in creating this project. This will include a critical analysis of the created game using survey data, the decision making behind the research, the design, and the implementation of the game and any methods used along the way. Additionally, the progress of the game has been recorded and tested using testing techniques (see Chapter 5) concerning the requirements (see Chapter 2). Lastly, a YouTube video has been created which shows the puzzle game being played. This video will cover all accessibility features that have been implemented (see Appendix 23).

1.2. Aim and Objectives

The project aims to create a game that offers players equal access through the implementation of accessibility features. The following objectives are:

1. Identify best practices within the industry for implementing accessibility features (literature review)
    a. Using the GAG website, gather four accessibility features, one for each impairment:
        i. Motor Impairment
        ii. Visual Impairment
        iii. Hearing Impairment
        iv. Cognitive Impairment
    b. Identify the laws and frameworks that govern accessibility
        i. Communications and Video Accessibility Act 2010
        ii. Equality Act 2010
        iii. Advanced Communications Services
2. Design game and accessibility features (UML Diagrams, Visual mock-ups)
    a. Design base concept of the puzzle game
    b. Design the accessibility features ready for implementation.
3. Build the base concept of the puzzle game
    a. Implement the base code required to make the game run.
4. Implement accessibility features within the game
    a. Implement accessibility features within the game.
5. Evaluate accessibility features (Playtesting and Survey)
    a. Fix any final bugs
    b. Create a survey to give to playtesters for evaluation.

1.3. Scope

The following section will determine items within the scope and items outside of the scope. Laws and regulations considered within the scope are the Communications and Video Accessibility Act 2010, the Equality Act 2010, and the Advanced Communications Services. Guidelines such as the Game Accessibility Guidelines will also be implemented within the puzzle game. The puzzle game will consist of a basic character controller allowing players to move, interact and jump. Other controls such as pausing the game will be considered. The game will consist of four playable levels, each showcasing its own unique accessibility features for impairments such as visual, cognitive, motor, and hearing. Section 8.1 provides further detail regarding these features. Other accessibility features such as highlighting text and keycode hints will be implemented within each level. The main menu will be included. This allows players to choose the playable levels, change their settings, read the controls, and exit the game entirely. All of which are controlled using a screen reader.

Impairments such as speech are considered outside of the scope. This is because no communication features such as a text chat are being implemented. Rendering the need for speech accessibility void. Game features such as difficulty levels are considered outside of the scope. Furthermore, as the game is more accessibility focused, more complex character controls such as sprinting, sliding, and crouching are considered outside the scope.

1.4. Structure of the report

Chapter 1 provides the background and motivation behind the project. It describes what the project will try to achieve and how it will do it (section 1.2). Furthermore, an analysis of features will be conducted to determine what is included within the scope and what is not included. The purpose of this chapter is to provide the reader with a basic understanding of the project.

Chapter 2 provides a more detailed view of the project's background. This chapter will detail the history behind the idea of the project, what other industries are doing in terms of accessibility, as well as detailing the importance of accessibility within the video game industry. The purpose of this chapter is to have the reader understand what the problem is, and how it can be solved.

Chapter 3 provides the project's functional and non-functional requirements. The chapter explains how requirements were chosen using specific laws and regulations. The purpose of this chapter is to provide the reader with enough detail so that they could develop the system that has been envisaged.

Chapter 4 provides information on the chosen methodology and how it was followed, detailing all possible research and design decisions, and how the final decisions were made. This chapter provides details regarding the CASE tools used, decisions made, how data will be collected, and the ethics of the project. The purpose of this chapter is to provide the reader with an understanding of how the game will be researched, designed, and how it will be implemented.

Chapter 5 discusses the decision-making processes on how final design choices were met. By using a range of problem-solving techniques, the chapter details how accessibility features were implemented and tested. The purpose of this chapter is to provide the reader with context on the decisions made, and why they were made.

Chapter 6 analyses and evaluates the gathering of survey data. The survey aims to generate positive feedback regarding the created puzzle game. The purpose of this chapter is to provide the reader with evidence that the project's aim was met.

Chapter 7 summarises the aim and objectives set out in section 1.2. It summarises how well they were achieved, any lessons learned during the project, what would have been done differently, and offers ideas for future work. Furthermore, a critical evaluation provides a detached view of the project and evaluates all aspects of the project. The purpose of this chapter is to highlight the key argument and present it to the reader.

Chapter 8 describes the amendments made throughout the project. Since the project proposal, changes have been made. Therefore, the purpose of this chapter is to provide the reader with an understanding of what has been changed and why.

Chapter 2: Project Background and Literature Review

2.1. Project Background

The following chapter will describe the history behind the project and why accessibility within video games is important. This chapter will try to bring awareness to the importance of equal access and offer suggestions for improvements, also highlighting the potential benefits that accessibility offers. Furthermore, the chapter provides a background on how the game is being created, what types of features are being included, and why they are being included. Finally, a literature review will discuss the current state of accessibility within video games, detailing how it can be improved. This will be done by analysing software and hardware that has been implemented within other industries and video games.

Accessibility within video games has seen improvements in recent years, however, there are still lingering issues within the industry. This report hopes to provide the preliminary data required for the introduction of certain accessibility features. More significant investments need to be made to ensure that equal access is being offered and potentially raise awareness on this topic (Aguado-Delgado et al, 2020). As mentioned before, guidelines such as GAG exist that offer insight into a substantial number of accessibility features and solutions. Four of these guidelines as identified in section 8.1 are going to be implemented within the puzzle game created in Unity. By implementing the identified guidelines in section 8.1, this report will encourage the idea of using accessibility guidelines, while also pushing the narrative towards the importance of making such guidelines a legal requirement within the industry. As found by Powers et al (2015), after examining all the laws regarding video games from different countries, only a little evidence of accessibility standards is identified (Powers et al, 2015). This can lead to an equal access issue for people with disabilities, however, if standards and general guidelines are implemented such as GAG, this can establish equal access for all players.

Implementing accessibility features is resource-intensive, however, video game accessibility offers financial benefits too. More than one billion people in the world have a form of disability which equates to around 14% of the entire population (World Health Organization, 2011). A game that implements more accessibility features will inherently encourage more players with disabilities to spend more on their game (PLUS QA, 2022). Not only will it increase the profits of the business, but it will also spread positive PR and free marketing through social media such as gaming review websites. This was evidently seen with the video game The Last of Us Part 2, which saw a substantial amount of PR with websites and blogs constantly talking about the game's never-ending list of accessibility features. Websites were even arguing if it is the most accessible game ever (BBC News. 2020).

The game that is being created on Unity will be a puzzle game. This genre was chosen because puzzles improve the way people make logical decisions. As stated by Bunt (2019), puzzle games focus on logical and conceptual challenges. Bunt (2019) also found from their observation findings that a participant demonstrated growth in their critical thinking skills. Therefore, a puzzle game would be beneficial to those that play it, especially those that are cognitively impaired. Additionally, design decisions from the GAG website will be implemented within the puzzle game. The chosen design decisions will be selected based upon diverse types of impairments sub-categorised by GAG. These impairments are motor, cognitive, visual, and hearing. For each impairment, one design decision that can cater to the impairment will be implemented within the game for a total of four design decisions. Furthermore, four other design decisions will be implemented which are control remapping, text size, colour-blindness, and subtitles. These four features are labelled by GAG as the four most complained about accessibility issues. As stated by GAG, accessibility means avoiding unnecessary barriers (Game Accessibility Guidelines, 2022). Therefore, by implementing these features within the puzzle game, people with disabilities should be able to better avoid those barriers and enjoy the game like anyone else. The four chosen design decisions from the GAG website will be explained and evaluated in section 8.1.

2.2. Literature Review

The main issue is that the current state of accessibility within video games is not good enough. This is summarised best by Brown and Anderson (2020) who state that there are issues needing to be addressed. Video games have room for improvement regarding accessible design. To further evaluate, research papers offer insight into the current state of accessibility by addressing the good and the bad. Powers et al (2015) offer insight into what the current state of video game laws and regulations looked like seven years ago in different countries, as well as why video game accessibility matters. After examining all the laws from the different countries, the authors found that none mention any sort of accessibility standards. Further into the paper argues for the creation of such legally enforceable accessibility standards for video games. Powers et al (2015) compare such needed standards to existing standards that are used in restaurants and government buildings which offer benefits economically, socially, and culturally. With no such legally enforceable accessibility standards for video games, a significant amount of people with disabilities may never obtain the benefits mentioned in section 2.1 (Powers et al, 2015).

A second paper by Costello et al (2019) found that accessibility features are being implemented in video games, however, equivalent to what was assessed by Brown and Anderson (2020), there is room for improvement. Costello et al (2019) ran tests on different video games and discovered that deaf and hearing-impaired gamers were facing accessibility issues. Although the paper uncovered good accessibility features, the issue is that most video games simply do not implement them into their development. Another paper, which was conducted by Wilson and Crabb (2018) covers mobile gaming accessibility. This paper discusses accessibility guidelines such as W3C and how it supports the development of mobile games. Their findings just like the above papers revealed that accessibility guidelines such as W3C and GAG need to be more apparent. As shown in section 8.1, the GAG guides the project on how accessibility features should be developed. However, implementing accessibility features sometimes can provide limitations to video games. Video games sometimes require fast responses which can present difficulties to players with disabilities. Slowing these responses down seems like a good idea, however, this could make the game less interesting and exciting (Hersh and Leporini, 2018).

Diverse types of software and hardware exist that will make implementing accessibility features easier. A software engineering practice known as the Model-View-Controller (MVC) can do this. The design pattern behind MVC consists of three parts, the model, the view, and the controller. As stated by Bucanek (2009) the model encapsulates information within objects, the view displays the object's information to the user and the controller implements actions within the objects (Bucanek, 2009). Developers could implement MVC to include accessibility. For example, including an adaptive controller. The developers could implement this by only having to modify the controller.

Frameworks such as the UI Accessibility Plugin (UAP) exist that cater to accessibility. UAP provides an Accessibility Manager which handles all UI elements within a Unity scene (see Appendix 02). The plugin can activate screen reader functionalities that will read out the name and type of any UI element. As stated within the documentation, the plugin will activate itself when it detects a screen reader, and use it for voice output (Metalpopgames.com, 2022). For example, if someone with screen reader technologies was to load up the puzzle game, the accessibility features will be automatically activated. However, this feature can also be manually activated.

A paper by Rodríguez et al. (2018) introduces CPR training for blind people in the form of a video game. The game consists of a series of mini-games that showcase the main steps to performing CPR. This is done through sound, vibration and tactile input and output. Their results indicated that after playing the game, participants' knowledge of CPR improved (Rodríguez et al, 2018). Another paper by Jaramillio-Alcazar et al. (2017) proposes an analysis tool for those who wish to develop mobile serious games for visually impaired people. This research aims to give support to those that are visually impaired and cannot access games due to their impairment (Jaramillio-Alcazar et al. 2017). These papers cover accessibility features excellently. However, their developments focus on a particular disability, rather than multiple disabilities. The next step in game development is to design for all approaches, developing games for disabled and non-disabled people with a wider range of features, including impairments (Hersh and Leporini, 2018).

Other industries such as the Web industry have made excellent developments by including accessibility features. Companies such as Apple are one of many representatives of advanced hardware and software, which includes products that make it easier for people with disabilities. For example, the Macintosh computer includes features such as screen-magnification, text-to-speech synthesis, voice recognition and visual alert cues (Carter and Markle, 2001). More recent discoveries by Taylor. (2018) found that free web accessibility tools exist. aXe is a Google Chrome or Firefox extension which will analyse the web accessibility of any institutional webpage. This software will allow web developers to identify possible accessibility issues and make changes accordingly (Taylor, 2018).

Overall, the interest in accessibility for video games is not a popular topic within the industry. This leads to an equal access issue. A person with disabilities will struggle to play certain video games or get stuck at certain points within a game, all because there are no accessibility features to support them. This is simply negligent of the industry because as evident from what Brown and Anderson (2015) addressed over seven years ago, these identified issues within the industry still exist today. Standards and general guidelines must be put in place for the industry to follow, which will provide equal access.

Chapter 3: Requirements Analysis

The following chapter will explain what the puzzle game should do. Functional and non-functional requirements will be listed and detailed explaining all aspects of the puzzle game. By analysing both the Trello Board (see Appendix 03) and the Project Plan (see Appendix 01) that were created in the project proposal, most functional and all non-functional requirements can be understood and clarified. The functional and non-functional requirements will be detailed enough that, if someone else was to design the puzzle game, they would be able to produce the system that has been envisaged. As for the accessibility requirements (see Section 3.1), they will require more examination as they will need to cover accessibility regulations such as the 21st Century Communication and Video Accessibility Act (CVAA) and the Advanced Communications Services (ACS).

Additionally, the requirements analysis is being employed to map out and design each stage of the game, by using the functional and non-functional requirements as a reference to what is required to make the game work. This will ensure that all aspects of the game have been designed (See Chapter 4). Furthermore, the functional and non-functional requirements will then be referenced again in the form of a checklist, this will ensure that all functional and non-functional requirements have been implemented (see Chapter 5).

3.1. Functional Requirements

Functional requirements are product features or functions that enable users to accomplish their tasks. They capture the intended behaviour of the system being created. This behaviour may be expressed as either a service, task or function the system is required to perform (Malan and Bredemeyer, 2001). Table 1 only accounts for the accessibility requirements as they are the most important, please see Appendix 04 for the full list of functional requirements. Even though all functionalities must be included, it is more important that the accessibility requirements meet the standards of regulations such as CVAA, AVS, and GAG. As mentioned in section 8.1, the accessibility functionalities cover cognitive, hearing, motor, and visual impairments, which are to be included. Furthermore, CVAA (which covers AVS) states that communication functionalities in games, such as UI must be made accessible. Therefore, screen reader functionalities are going to be required. This will ensure that communication between the UI navigation and the player exists (Federal Communications Commission, 2018).

Accessibility	
The system will have visual accessibility features within the game	1
The system will have cognitive accessibility features within the game	1
The system will have hearing accessibility features within the game	1
The system will have motor accessibility features within the game	1
The system will allow a user to turn on/off accessibility features	2
The system will include screen reader functionalities	1

Table 1 - The Accessibility Functional Requirements

3.2. Non-Functional Requirements

Non-functional requirements define the puzzle game attributes such as performance, usability, and accessibility. Non-functional requirements do not describe what the game will do, but how the game will do it (Chung et al, 2011). Also known as system qualities, they are critical to the functionality of the puzzle game as they ensure the usability and effectiveness of the entire game. Failing to meet even one of these requirements can lead to the game crashing or not meeting performance standards, resulting in unsatisfied users. Appendix 05 provides the non-functional requirements table. Please refer to Appendices 06 through 11 to see how each non-functional requirement was checked. The accessibility within the game must work as intended. If the survey data from Chapter 6 is sufficient, then it can provide the required results to complete the accessibility requirement.

Chapter 4: Design and Methods

The following design and methods chapter will explain the choices and final decisions made along the way that led to the design of the puzzle game. An analysis regarding the chosen methodology and CASE tools will be detailed below explaining the advantages they offer to the project, as well as how they will support the development process of the puzzle game. CASE tools used within this project are use case diagrams, a class diagram, and a survey.

Firstly, use case diagrams will demonstrate all interactions a user can have within the game. Secondly, a class diagram will be created to show the structural and behavioural features within the game. Thirdly, the survey will generate feedback regarding the in-game accessibility features. Additionally, alternative research methods will be discussed, detailing why they were not used.

4.1. Methodology

The development method being used throughout the project is Extreme Programming (XP). XP uses iterations and small releases throughout the project. What the small releases allow for is progress reviews throughout the project. Project work will be completed in short cycles (iterations) and will be continuously tested between each cycle. This ensures that bug fixes are identified and quickly amended before moving on to a new iteration. As shown in Chapter 5 of the report, implementation of the game does not continue until the testing phase of a current iteration is successful. Therefore, each iteration will be delivering fully developed and tested software that meets a small set of the project's requirements (Lindstrom and Jeffries, 2003). Figure 1 shows each stage of the software development life cycle for XP. The stages of the life cycle will be discussed regarding what was done.

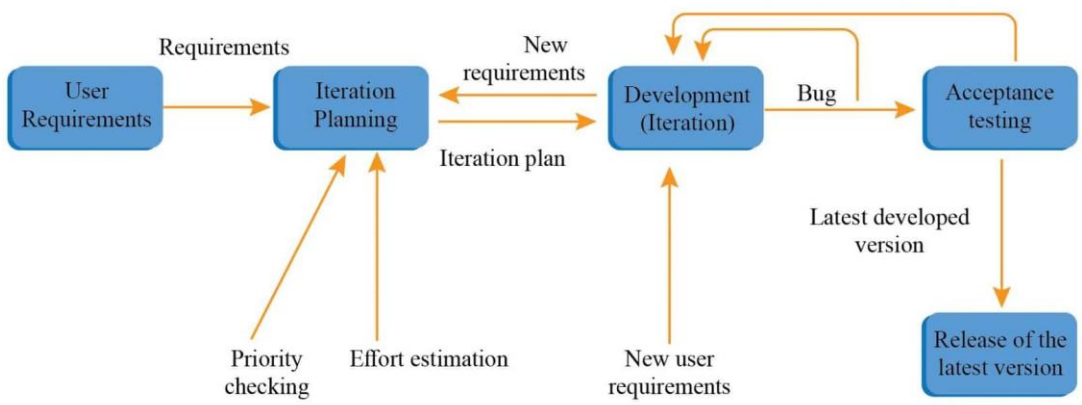


Figure 1 - Extreme Programming (Singh, 2022.)

The user requirements were collected using both the Trello Board (see Appendix 03) and the Project Plan (see Appendix 01). By analysing the milestones set within the Project Plan (see Appendix 01), the user requirements can be split into a list of iterations. The iterations are planned out to ensure that the important features of the puzzle game were developed first (see priorities in Appendix 04). If new requirements were needed, these could be added after an iteration is developed. As mentioned above, the iteration cycles will be completed in short cycles and acceptance testing will be conducted on each iteration before moving on to the next. After each acceptance test, the latest version of the game will be updated.

The reasoning behind choosing XP is its advantages. As the development of the project must be completed within 5 months, certain methodologies simply will not work. Fast-paced methodologies are required, and XP is one of them. As stated by Shrivastava et al (2021), XP is an extremely time-efficient and lightweight development technique. The waterfall methodology would also be a good option; however, feedback can only be generated at the end of the software development, which will not allow for changes in requirements if needed (Adenowo and Adenowo, 2013). XP can generate feedback freely between iterations and will be necessary within this type of project.

4.1.1. Ethics

The following section will cover the ethical considerations regarding the Ethics Policy for Undergraduate and Taught Postgraduate Research (EHU Guidance, 2022). Any sections referenced here will be referring to the Ethics Policy, not the report itself.

4.1.1.1. Informed Consent

All participants taking part in this project will be issued a Participant Information Sheet (see Appendix 24) in abidance with Section 1.2. Consent will be obtained by the Participant Consent Form (Appendix 25) and verbally as per Sections 1.2.6 and 1.2.8. This is after the participants have read through the Information Sheet. The research being conducted within this report will not consider any high-risk research but will conduct mainly, low-risk and minimal-risk research, as per Section 1.2.1. The Survey (see Appendix 19) and the Participant Information Sheet (see Appendix 24) will cover the ethical statements as per Sections 1.2.3, 1.2.4 and 1.2.5. Thus, all participants will be made aware of what the project is and the objective the survey is trying to achieve. Participants can withdraw from the survey; however, their data will need to be identifiable to remove it. Therefore, the Data Protection Act 2018 (Data Protection, 2022) will protect the collected survey data to ensure all participant data is rightfully protected. Further information for the survey can be found in Section 6. Sections 1.2.7, 1.2.9, and 1.2.10 will not be broken as no interviews or recordings of the participants will be conducted.

4.1.1.2. High-Risk Research

None of the research carried out within this report is considered high-risk. Therefore, none of the statements determined in Section 2.1 needs to be carried out.

4.1.1.3. Low-Risk Research

All research and data collection being conducted includes statements mentioned within Section 2.2.3. Therefore, all survey research and data collection can be considered low risk.

4.1.1.4. Minimal Risk Research

All other research can be considered a minimal risk as it does not involve any possible legal, social, or ethical implications, as per Section 2.3.2. All authors of academic research will be credited using Harvard referencing (see References). The puzzle game will adhere to PEGI (Pan European Game Information) guidelines, and as such the game should be considered a PEGI 3 video game, as no mild or graphic violence is being used (Pegi Public Site, 2020). Also, assets included in the game will be implemented from the Unity asset store. However, all free assets can be used for commercial use, and any purchased assets become the consumers to do with as they please (Unity, 2021).

4.1.1.5. Ethical Approval Process

Section 3.1 of the approval process has been covered as per the self-assessment checklist (see Appendix 26). The self-assessment checklist has been signed and approved by the supervisor as per Sections 3.2 and 3.3.

4.2. Use Case Diagrams

Use Cases are a powerful tool to capture functional requirements for software systems (Bertolino et al, 2002). A Use Case describes the interaction between a system and its environment, an external actor usually triggers this, for example, the player of the puzzle game. When the trigger is activated by the primary actor (the player), the system will execute the Use Case to achieve its goal. Use Case descriptions can also include extensions to the sequence which can satisfy the goal or can lead to failure. An extension leading to failure would be when a player types the password wrong (see Appendix 13).

Following the functional requirements created within Chapter 2, various use case diagrams have been developed. Brainstorming techniques have been conducted to determine which use cases should be chosen for the final design. Upon analysing the various use cases, final use case diagrams have been developed (see Appendices 12 through 14). The alternative use cases can still be seen with Appendices 15 through 17. Section 4.3 will provide reasons why the final design decisions were made.

4.3. Design Choices

After creating the Use Case diagrams and all alternatives, design choices can be planned out and examined before the outline of the class diagram is created. The class diagram must be done correctly, as it plays an integral role in the implementation process. Therefore, when design decisions are being made, it is also important to ensure all aspects are considered, and that the final decisions regarding all aspects are what is best for the puzzle game.

4.3.1. Interactable Objects

Interactable Objects such as opening doors, picking up objects, and typing in passcodes are the key features of the puzzle game. As shown in the In-Game Use Case (see Appendix 13), interactable objects are a huge part of the game. Therefore, they must be designed correctly. When designing interactable objects, questions need to be thought about. How does the player know they can interact with objects? Does the player need to press or hold an input key to interact?

It is also important to keep in mind that equal access for players is essential. Therefore, keeping interactions simple and concise is important. As stated by GAG, holding requires much greater motor skill than pressing (Game Accessibility Guidelines. 2022). Furthermore, support for motor skills is one of the project requirements as mentioned within the Scope (see Appendix 02), meaning that holding inputs will be going against the very thing the project is trying to accomplish, this also applies to visual, hearing, and cognitive impairments too. Therefore, when designing interactable objects for the game, keeping the code to a simple press input would be best.

4.3.2. User Interface

As for the first question, players who may struggle to understand that something can be interacted with are cognitive impaired users and visually impaired users. Therefore, a design for both these impairments is essential. Designing complex User Interface (UI) systems can make for a fun and interactive game. However, a strategy identified by Yuan, Folmer and Harris (2011) is to limit the number of visual stimuli a cognitively impaired player receives (Yuan, Folmer and Harris, 2011). Therefore, complex UI systems should be avoided and only the essential information is given to the players.

Furthermore, visually impaired players will need to understand the UI elements. This can be done in diverse ways, by simply making larger and bold text. However, visual impairments can differ, sometimes making larger text might not be enough for visually impaired people. So, to give equal access, a screen reader is required. Therefore, as shown in the UI Use Case (see Appendix 14), any time UI elements appear on screen or the player hovers over UI elements within a menu, the screen reader will read out the UI element text and declare what the UI element is. Lastly, an option for enabling and disabling accessibility features is also included, this is an option for those that want to still play the game, but do not require any of the accessibility options the game offers.

4.4. Class Diagram

The UML Class diagram is the most appropriate tool to describe a complete understanding of the requirements (Abdelnabi et al, 2020). A Class diagram can map out the structure of a system (the puzzle game) by showing its classes, methods, variables, and relationships between other objects. This showcases a static view of the system and provides a blueprint on how to construct the executable code for the system. Even though XP offers flexibility in its design stage (Ahmed et al, 2010), it is still important to ensure the core foundation of the implementation stage is correct and follows the direction given by the Class diagram.

After final decisions were made, and by following the guidance of both the functional requirements and the final use case diagrams, a Class diagram has been developed (see Appendix 18). As mentioned above, though the flexibility within XP exists, ensuring that the Class diagram provides the correct direction for the project is important, as creating a class diagram is both complex and time-consuming (Fernández-Sáez et al, 2013).

All methods and variables will be written in C# scripts using Visual Studio 2019. Any Unity script that is created will derive from the ‘Monobehaviour’ base class. Lastly, to make accessibility features work, all scripts that involve UI elements will also derive from the ‘UAP_AccessibilityManager’ and UAP_BaseElement classes. Please see the UAP documentation for more information on these two classes (Metalpopgames.com, 2022).

4.5. Survey

For this project, a concurrent mixed method design will be conducted. This type of design method collects both qualitative and quantitative data during the same stage (Castro et al, 2010). Three of these methods exist that were identified by Creswell et al. (2003). These are the concurrent triangulation, concurrent nested, and concurrent transformative designs (Creswell et al, 2003). For this project, concurrent triangulation will be used.

4.5.1. Concurrent Triangulation

Concurrent triangulation design involves a single study which will contain qualitative and quantitative data (Kroll and Neri, 2009). As the name suggests, the two types of data will be collected at the same time. The purpose of this design method is to validate the findings generated by comparing the two sets of data.

4.5.2. Participants

Participants who take part in playing the game will need to provide feedback, this feedback will be regarding the in-game accessibility features. As stated by Kelley (2003), survey research is a unique way of gathering information as its research produces data based on real-world observations. It will be important to get feedback from different perspectives, as participants can ensure that the accessibility features are working as intended and offer insight into how well those features helped them complete the game.

4.5.3. Survey Questions

As stated in section 4.5.1, the survey will consist of both quantitative and qualitative questions. The quantitative questions will provide numeric and measurable results as to how well the accessibility features work within the game. The qualitative questions will provide contextual and open-ended results such as the user experiences of each of the participants that take part in the survey. The goal of the survey will be to generate positive feedback from the participants, this feedback can then be used to support the overall aim of the project.

4.5.4. Pretest Survey

A pre-test survey will also be conducted to ensure the validity and reliability of the real survey. The pre-test survey will consist of four additional questions. The data gathered from these four selected questions should provide sufficient information to form the relevant changes required. The real survey can then be amended using the data collected to create a survey that makes sense, is unbiased, and gathers relevant information. Chapter 7 of the report will analyse the gathered data for both the pre-test survey and the real survey.

4.6. Alternative Approaches

Other types of research methods were considered, such as observations and focus groups. These two types of research methods offer diverse advantages compared to the survey research that was undertaken. However, their limitations and pitfalls far outweigh the benefits. Observational research can be quick and cheap to conduct, however, as the researcher is not an independent observer, this can bring a lack of objectivity. Furthermore, participant observation carries potential concerns that the presence of an investigator may influence the way the participants behave (Iacono, Brown and Holtham, 2009). This can lead to potential bias, resulting in the overall data being corrupted.

Placing participants into focus groups offers advantages as well, as this presents in-depth discussions with the potential for new points of view regarding the puzzle game (Litosseliti, 2003). However, this can bring similar issues of participants feeling influenced by others within their group. It is easy for the more confident participants to voice their opinions, which can potentially influence the opinions of others. Therefore, by conducting a survey any potential bias or influence can be avoided, as all participants have their own opinion regarding the puzzle game.

Chapter 5: Implementation and Testing

The following implementation and testing chapter will discuss the issues involved in certain decision-making processes regarding the accessibility features. Each accessibility feature will be discussed regarding how the final design choices were met, and why other alternatives were not taken. The following sections will explain how each feature was implemented using problem-solving techniques and testing the feature works through input validations. The accessibility features that have been included are visual, hearing, motor, and cognitive accessibility features. Furthermore, core game features such as character interactions will be discussed, as this includes accessibility features too. Acceptance testing will be completed for each section as well, this is to ensure that the features work as per the functional requirements (see Section 3.1).

5.1. Level 01 Visual Accessibility – Text to Speech

Visually impaired players may find it harder or even impossible to receive visual feedback from video games (Yuan, Folmer and Harris, 2011). Unique features exist that can cater to the visually impaired, including features such as increasing font sizes and the ability to zoom in. However, these types of features are not good enough for people who are more visually impaired than others. Therefore, text to speech functionalities was implemented. As found by Yuan, Folmer and Harris (2011) replacing visuals with a form of feedback that the player can still perceive is the best course of action.

5.1.1. Implementation

To implement the text to speech feature, an asset called UI Accessibility Plugin (UAP) was imported into the project. As mentioned within section 4.4, all UI elements incorporate the UAP_Accessibility_Manager and UAP_BaseElement classes. With UI elements deriving from the two classes, all objects with text elements can now enable the text to speech feature from the screen reader. Therefore, any time in-game text appears, or the player is hovering over a UI object with text, the text will be read out to the player. The code snippet from the 'UAP_AccessibilityManager.cs' script (see Figure 2) provides context on how the text to speech feature is implemented.

Many trial and error techniques were conducted to ensure that this feature worked as intended. This is due to the vast amount of features the UAP framework offers. Appendix 02 provides only a snippet of features this framework offers. Therefore, it was important to ensure that this feature was fine-tuned to offer the best possible user experience. Furthermore, the same technique was conducted in section 5.4.1 and other features that use the UAP framework.

```
void ReadValue(bool allowPause = true, bool interrupt = false)
{
    if (m_CurrentItem == null)
        return;

    // Support Value reading as AudioClip
    AudioClip audio = m_CurrentItem.m_Object.GetCurrentValueAsAudio();
    string valueText = m_CurrentItem.m_Object.GetCurrentValueAsText();

    if (audio != null || (valueText != null && valueText.Length > 0))
    {
        if (allowPause)
            SayPause(instance.m_ValueDelay);

        SayAudio(audio, valueText, UAP_AudioQueue.EAudioType.Element_Text,
                m_CurrentItem.m_Object.m_AllowVoiceOver, interrupt ?
                UAP_AudioQueue.EInterrupt.Elements : UAP_AudioQueue.EInterrupt.None);
    }
}
```

Figure 2 – Text to speech code from the UAP_AccessibilityManager.cs script

5.1.2. Testing

To test that this functionality works, the screen reader will apply a green border to the surrounding element to show it has been highlighted. The text to speech feature will read out any text within the element and explain what type of UI is highlighted. For example, in figure 3 the screen reader will read out ‘Start Game, Button’. Furthermore, the screen reader will also enable ‘onHover’ events. This is a method that will be called when a button is being hovered over. ‘onHover’ will make the highlighted button turn yellow to further indicate this is the highlighted button.

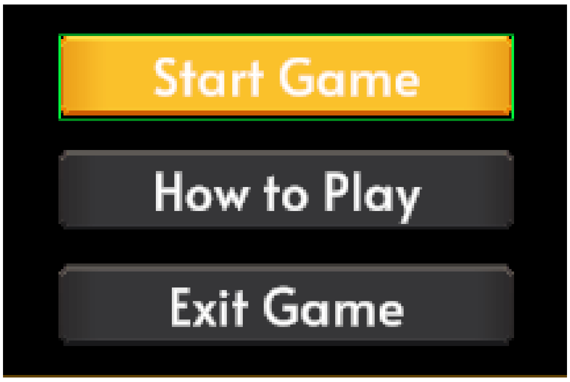


Figure 3 - Screen Reader hovering over Start Game

5.2. Level 02 Cognitive Accessibility – Hot and Cold Meter

Cognitively impaired players may find it hard to understand what they need to do or where they need to go. Therefore, guiding the players to the correct location would be a promising idea to ensure that they do not get lost. As mentioned in section 8.1, providing the players with contextual in-game help would be beneficial (Game Accessibility Guidelines, 2022). For this, a hot and cold meter will be implemented. Other elements such as reminders and highlighting important words do not provide sufficient benefits compared to the hot and cold meter, as this would only be enabled once the player finds the keycode (see Section 5.5), it is more important that the player finds where the keycode is.

5.2.1. Implementation

To implement the hot and cold feature, a brute force technique was first used to determine the furthest possible distance the player character could get from the keycode and then the closest. This would determine the two variables used to create the slider object. Once this was complete, a simple check distance method was created to determine how far away the character was from the keycode. Lastly, the meter will disappear once the keycode was picked up, this is to stop any confusion that the player still needs to look for a keycode. The code snippet from the ‘DistanceFromPlayer.cs’ script (see Figure 4) provides context to how this feature was implemented.

```
void CheckDistance()
{
    //Gets the distance between the keycode object and the player object
    float dist = Vector3.Distance(key.transform.position,
                 player.transform.position);

    //Converts the distance into a decimal percentage (e.g: 0.40, 0.60, etc)
    percentDist = dist / highestDist - lowestDist;

    /*Sets the slider value of the hot and cold meter
    Higher the value, the closer the player is to the object */
    slider.fillAmount = percentDist;
    print("Distance from Keycode: " + dist);

    //Disables the hot and cold meter once the key is found
    if (remember.activeInHierarchy)
    {
        hotColdMeter.SetActive(false);
    }
}
```

Figure 4 - Code from the DistanceFromPlayer.cs script

5.2.2. Testing

To test that this functionality works, the player character will stand at different positions to prove the meter works as intended. As shown in figure 5 the drawer that the character is looking at is where the keycode is hidden. And as shown on the hot and cold meter, it is much hotter than in figure 6, which is further away from the keycode location. Furthermore, the console provides the exact distance the character is from the keycode. Again, as shown in figure 5, the character has a distance of 3.30 meters, compared to figure 6's 17.37 meters.

Figure 6 - Character is far away from the keycode

Figure 5 - Character is close to the keycode

5.3. Hearing Accessibility – Visual Sound Indicator

Audio can play a significant role in video games, both sounds and music can add extra layers to a game's experience. Games even use sound as their main feature (Yuan, Folmer and Harris, 2011). However, players who have hearing impairments will have their experience reduced or removed entirely depending on their level of deafness. Therefore, the audio must be replaced with something else, such as text. To indicate directional sounds, closed captioning will display an audio cue event, which the player can activate using the C key. This will display an indicator arrow at the top of the screen. The arrow object will help those with hearing impairments to find where the sound is coming from.

5.3.1. Implementation

To implement the arrow indicator feature, a 2d arrow will be displayed as UI on the canvas. At first, this was a clever idea, however, a bug occurred that rendered the arrow unreadable. A lot of brute force problem-solving techniques were tried and tested when a new idea arose. Instead of having the arrow on the canvas of the UI, a 3d arrow object can be hovered over the player character (see Figure 7). This solved any issues occurring with the 2d arrow object and the code is much less complex too.

Figure 7 - Arrow object hovering over the player character

The code snippet from the 'EnableArrow.cs' script (see Figure 8) provides context to how this feature was implemented. The 'activateArrow()' method from figure 8 is activated using Unity's new Input System, which will be Invoked when the C key is pressed.

```
public void Start()
{
    //Arrow is disabled on start
    arrow.SetActive(false);

    //Retrieves the keycode object from the level
    key = GameObject.Find("dfk_crate_04_c");
}

// Update is called once per frame
Unity Message | 0 references
void Update()
{
    //Sets scriptable object (the arrow) to point towards the key object
    transform.GetChild(0).LookAt(key.transform.position);
}

//Activates the coroutine of EnableArrow()
1 reference
public void  activateArrow()
{
    StartCoroutine(EnableArrow());
    print("Key Pressed: Arrow Enabled");
}

//Enables the arrow object for 2 seconds before disabling it.
1 reference
IEnumerator EnableArrow()
{
    arrow.SetActive(true);
    yield return new WaitForSeconds(2);
    arrow.SetActive(false);
}
```

Figure 8 – Code from the EnableArrow.cs script

5.3.2. Testing

To test that this functionality works, the player can use the C key to enable the arrow object (see Figure 7). Once enabled it can be seen within the console (see Figure 9) that the input has been received and that this input enables the arrow object. Figure 9 also shows the arrow object again, directly pointing at the keycode location, further proving this feature is working as intended.

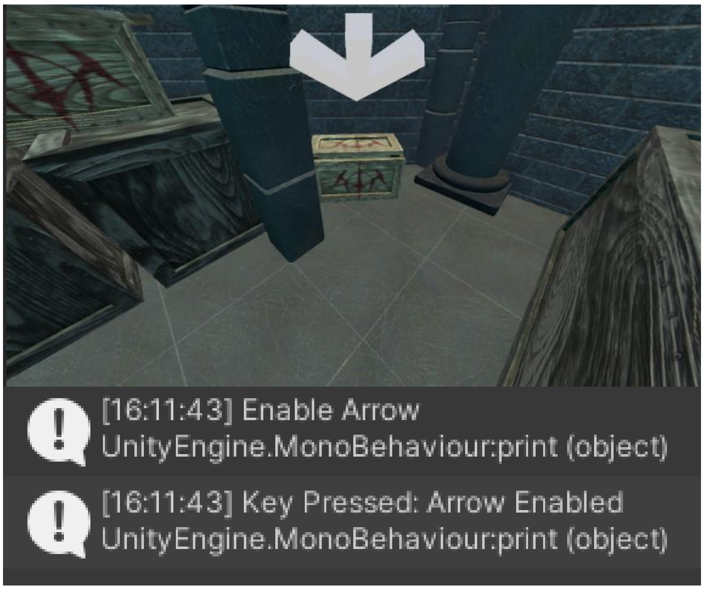


Figure 9 - Arrow pointing at keycode location. Console shows arrow being enabled.

5.4. Motor Accessibility – Screen Reader

Motor impaired players can find it problematic or impossible to use conventional input devices such as a mouse (Yuan, Folmer and Harris, 2011). One important design feature is to ensure that the input operations within the game are reduced (see Section 4.3.1). However, for those on the more severe side of motor impairment, this might not be enough. Therefore, navigation of the UI within the game can be controlled using the screen reader (arrow keys) instead of the mouse. Inputs for keyboard devices require one push of a button, compared to a mouse which uses the motion of a hand. Thus, the screen reader should drastically improve the experience for those who are motor impaired.

5.4.1. Implementation

The screen reader is implemented using the same classes as section 5.1.1 as they both derive from the UAP_Accessibility_Manager and the UAP_BaseElement classes. If all the required UI elements derive from this class, the UI can enable the screen reader functionalities and can be navigated using the arrow keys accordingly. The code snippet from the 'UAP_AccessibilityManager.cs' script (see Figure 10) provides context on how the navigation is handled, using the arrow keys.

```
// Arrow keys to navigate
if (Input.GetKeyDown(m_NextElementKey))
{
    IncrementUIElement();
    return;
}
if (Input.GetKeyDown(m_PreviousElementKey))
{
    DecrementUIElement();
    return;
}
```

Figure 10 - Navigation code from the UAP_AccessibilityManager script

5.4.2. Testing

To test this functionality works, the keycode from Level 04 was interacted with (Section 8.1 describes Level 04's main feature). As shown in Figure 11, the keycode is not being controlled by the mouse, but by the screen reader. Arrow keys can determine which button is selected, upon pressing the Enter key, the onClick event for the selected button will be invoked.

Figure 11 - Code Panel being controlled with the screen reader

5.5. Other Smaller Accessibility Features

This section covers the smaller features that have not been mentioned previously, which have benefits that can prove useful to those with cognitive impairments. The two other features are highlighting important text within the game (Figure 12) and reminder messages (Figure 13). As stated by the GAG, indicating reminders of objectives, and highlighting important texts can be proven beneficial (Game Accessibility Guidelines, 2022). Implementing highlighted text is a straightforward process, as it can be done by changing the colour of the text and making it bold, this ensures that the text stands out to the reader. For reminders, once the keycode UI is closed, a reminder message will remain on screen, meaning the player does not have to memorise the keycode.

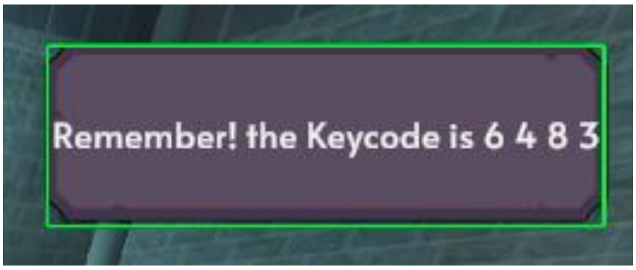


Figure 13 - Remember message showing the keycode

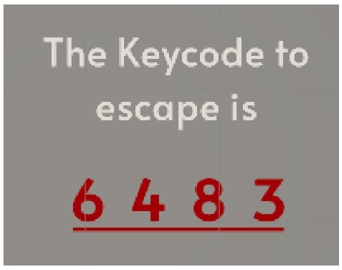


Figure 12 - Keycode book text

Chapter 6: Data Gathering and Analysis

The following section describes the survey's findings through analysis and evaluation. As stated in Section 4.5, The goal of the survey will be to generate positive feedback from the participants, this feedback can then be used to support the overall aim of the project. The data findings are split into two sections, one for the pre-test survey and the other containing the final survey data. The following surveys will be web-based, as this will provide unique opportunities for gathering data through online data collection. As stated by Lefever et al. (2006) online data collection can be useful for pretesting surveys and gathering preliminary data, which can prove beneficial when conducting the actual survey itself (Lefever et al, 2006). The survey will consist of ten questions. As the questions will be both quantitative and qualitative, the results will be both measurable and open-ended, respectively.

6.1. Survey Data (Pre-test)

Before conducting the real survey, a survey pre-test will be required. This involves conducting a draft revision of the survey for a select number of people. Pre-testing is an essential step in the survey's development process, as it will increase the validity and reliability of the survey's evidence(UCLA, 2022). It means that any problems with the survey can be managed before sending it out to the participants. Any potential questions that may not make sense or seem to form sources of bias can be identified and amended. Questions within table 2 will be used to identify any potential issues within the survey.

Question Number	Question
1	Was the questionnaire comprehensive? Was the topic covered adequately?
2	Are there any questions you expected to answer that is not in the survey?
3	Are there any questions you feel may be too sensitive or that may affect the response rate that should be considered deleted?
4	Was the questionnaire too long, too short, or about right?

Table 2 - Pretest Survey Questions

6.1.1. *Analysis of survey data*

After collecting the data from all the participants of the game, the questions from table 2 received positive feedback regarding the survey. All participants agreed that the survey is comprehensive and covers the topic of the project well enough that it does not need to include any other type of questions. One participant stated that “the questions cover the topic really well and make you think outside the box”. As shown in the quantitative data (Appendices 20 and 21), it provides enough evidence to believe that no amendments need to be made before conducting the real survey. Therefore, the survey questions will not need to be amended and the survey data can start to be collected.

6.2. Revised Survey Data

With the completion of the pre-test survey, the initiation of the real survey could begin. This survey collected data from multiple participants, where all participants are asked to complete all four levels of the puzzle game. This allowed the participants to answer the survey questions to the best of their ability. The results of the survey can be found in Appendix 22, which provides all quantitative data, and table 3, which provides all qualitative data. The following section will analyse the data collected from the participants and evaluate how the results compare to the aim of the project.

6.2.1. Analysis and Evaluation of survey data

When analysing the collected quantitative data (Appendix 22), it can be concluded that all accessibility features within the puzzle game not only worked as intended, but they helped all the participants who played the game. The quantitative data only resulted in answers of ‘very helpful’ or ‘extremely helpful’, which provides great evidence for the outcome of the project. Moreover, Level 3 received perfect results, resulting in 100% of participants saying the feature was extremely helpful.

Reference #	**Question #**	**Qualitative Data Result**
1	**8**	On level 04 it was confusing switching from using the mouse to enter the keycode to using the arrow keys. It wasn't explained enough.
2	**10**	Adding keybindings to allow players to choose how they control the game.
3	**10**	Yes, it would have been nice to see color blind mode, which supports different types of color blind filters.
4	**10**	Key rebindings

Table 3 - Qualitative data results

The qualitative data also receives comparable results. One question asked was regarding the state of the accessibility features, which resulted in all participants agreeing that the features worked as described. One issue arose regarding question 8, which asked participants if any part of the game was more confusing than the rest. One participant stated that Level 04 was not explained good enough as it was confusing for them (see table 3, reference 1). In conclusion, the results of the survey verify that the aim of the project was achieved. All but one of the participants managed to complete the game without any confusion and all participants provided applause for the created game.

Finally, one last question was asked of the participants, which was to state any accessibility features that could improve the game. The results for this question have been included in table 3 and will be discussed within Chapter 7 of the report.

Chapter 7: Conclusions

7.1. Summary of Report

To summarise, the project's aim and objectives were followed and achieved. Best practices for implementing accessibility features were identified by incorporating advice from the Game Accessibility Guidelines. Several types of accessibility features have been implemented that cover the four main impairments mentioned within section 1.2, such as a screen reader or the contextual guides within the levels. Laws, regulations, and accessibility guides such as the Equality Act 2010, GAG, CVAA, AVS, and FCC were examined. They helped guide the project to the correct outcome by providing best practices and advice (see Section 3.1).

UML diagrams such as Use case and class diagrams were developed to help design the base concept of the game, as well as how to implement the accessibility features. As alternative mock-ups were created, analysis and evaluation of the unique designs were required (see Section 4.3). With the chosen designed concepts in mind, the Unity engine, combined with Visual Studio 2019 was used to develop, code, implement, and test the puzzle game into iterations, as described by the Extreme Programming methodology (see Section 4.1). As shown in the class diagram (see Appendix 18), an asset known as UI Accessibility Plugin (UAP) helped develop and implement the accessibility features into the game.

Finally, the data gathered in section 6.2 revealed that the project can be considered a success when evaluating the results against the aim of the project. Additionally, the feedback in the survey provided great advice for potential future work and updates for the puzzle game. However, limitations within the puzzle game were met. Extra features such as key rebinding and colour-blind mode could not be implemented, this was due to both time constraints and incomprehension when it came to implementing the missing features. Data gathered from the survey revealed that these two specific features would have been great additions to the game (see results in table 3). Although, it is hopeful that these features will be implemented in the future (see Section 7.3).

7.2. Critical Evaluation

Overall, this project has done an excellent job of delivering its aim and objectives. As mentioned in section 7.1, all objectives that were set in the project proposal have been delivered to the best of their ability. Analysis of the Scope reveals that all deliverables, project requirements and milestones were all completed on time as per the project's constraints. Additionally, any potential risk of legal, social, or ethical implications was correctly covered. All participants were made aware of the survey's objectives and all ethical bases were covered (see Appendix 19). Throughout the development, different types of problem-solving techniques were used such as brute force and brainstorming. The following sections will reflect on each of the main stages of the game's software development and data gathering.

7.2.1. Functional and Non-Functional Requirements

The functional and non-functional requirements that were implemented ensured that the game worked as intended, allowing players to gain the benefits given by the accessibility features. In terms of the base game functionalities, player movement, controls, and collisions were tested and fine-tuned to ensure that the game played smoothly, and without bugs.

7.2.2. Project Design

Throughout the software development life cycle, unique design decisions were considered. Different methodologies such as XP and Waterfall were considered as their advantages are similar. Although, as stated in section 4.1, XP's advantage for permitting feedback to be generated freely was vital to this project. As explained in section 8.1, amendments to the project's requirements were mandatory, and this could not have been possible using a methodology such as Waterfall, without having to start the design of the project over. Furthermore, distinctive design decisions regarding how the player will interact with the game were considered. As shown in appendices 12 through 17, multiple use cases were designed. The use cases were analysed with accessibility in mind, to understand which use cases better suited those with impairments. Overall, the right sets of use cases were chosen. No interactable objects or UI within the game required more than a single input.

7.2.3. Project Implementation

The implementation of the accessibility features was a success. All features were created using the Unity engine, which is coded using C#. Visual Studio 2019 was used to implement the code, where all classes are derived from the MonoBehaviour class. Any objects that included accessibility features were also derived from the UAP_Accessibility_Manager class. However, modification of classes was required. One of these changes is mentioned in section 5.3.1 regarding the 2D arrow object. Another change was implemented within the player controller script file. It was discovered that Unity's newer Input System (Docs.unity3d.com, 2022) offers better control over various aspects of the Input System.

7.2.4. Data Gathering and Evaluation

The survey data provided crucial information in understanding the value of what accessibility features can offer. Amendments to the survey were considered, however, the results of the pre-test survey found that no amendments were required. The positive feedback the survey received will be used to develop a stronger view, which will achieve the aim set out by this project. However, part of the feedback did provide open-ended answers (see Table 3) that will be analysed. These answers will prove useful if future work on the project will commence.

7.2.5. Lessons Learned and What Would be Done Differently

Throughout this project, much of what was learned was through trial and error. This was mostly due to a lack of experience and poor design choices. If the project was to be conducted again, one aspect of the development that should be improved upon would be the design phase. As shown in section 5.3.1, the problem with the 2d arrow arose from bad design choices. Therefore, by ensuring that the design phase is better developed, the implementation of the puzzle game could have been accomplished better.

Another action that will be considered in the future is ensuring that bugs are correctly tracked and documented. As explained by IBM (2022) a good quality assurance process can uncover hundreds of defects (IBM, 2022). Therefore, implementing a bug tracker can improve efficiency by helping prioritise, monitor, and report on each bug.

7.3. Future Work / Directions

The survey data gathered from table 3 offers accessibility ideas to further improve upon the created puzzle game. Two great ideas that were mentioned were key rebinding and colour-blind mode. Unfortunately, the project plan did include the two features to be implemented, but time constraints and the complexity of the features made these features unfeasible, and therefore they had to be left out. However, this does not need to be the end of the project. The data collected within table 3 can direct future work for the project. Therefore, implementing more accessibility features such as key rebinding and colour-blind mode is feasible for future work. This will also include making the game smoother by ironing out any potential bugs that have gone unnoticed.

Chapter 8: Reflection

8.1. Amendments from the Original Proposal

Part of the project plan was to decide upon five distinct types of accessibility features that will be created within the video game, the accessibility features will be based upon guidelines from the GAG website. This has now been changed to four accessibility features and will be updated in the aims and objectives section and the project plan accordingly. The reasoning is that only four sub-categories of impairments exist on the GAG website. Therefore, each of the four accessibility features and its impairment will be showcased within its own level of the puzzle game. These four have been chosen because as stated by GAG, they are beneficial to many people and good game design (Game Accessibility Guidelines, 2022). This will also decrease the workload required to complete the project as it was very time constraining in the first place. Running up to deadline day. The four accessibility features and their corresponding guidelines based upon the GAG website are:

1. Visual Impairment - Ensure that there is screen reader support, including menus & installers (Game Accessibility Guidelines, 2022). This feature will be demonstrated within Level 01 of the puzzle game. The screen reader will read out text on the wall to aid those that are too visually impaired to read it themselves. This text is required to escape the level. Additionally, all the text within the menus of the game will be read out by the screen reader too.

2. Cognitive Impairment – Include contextual in-game help/guidance/tips (Game Accessibility Guidelines, 2022). This feature will be demonstrated within Level 02 of the puzzle game. A Hot and Cold UI will appear on-screen to aid those in need of directions to find a key to escape the level. The user will be told if they are getting closer to the required key through the UI. This will aid those with cognitive impairments in figuring out how to escape.

3. Hearing Impairment – Ensure that all-important supplementary information conveyed by audio is being replicated in text/visuals (Game Accessibility Guidelines, 2022). This feature will be demonstrated within Level 03. This level will play no sound to mimic that of someone who is playing the game with a hearing impairment. Subtitles and visual indicators will be shown on screen to aid the player and help them navigate their way to the key to escape the level.

4. Motor Impairment – Ensure that all areas of the user interface can be accessed using the same input method as the gameplay (Game Accessibility Guidelines, 2022). This feature will be demonstrated within Level 04. To escape a keycode will need to be entered. However, this time

the movement keys will be used to enter the code. Aiding those that are motor impaired, so they do not have to click each button to escape the level.

References

Abdelnabi, E., Maatuk, A., Abdelaziz, T. and Elakeili, S., 2020. Generating UML Class Diagram using NLP Techniques and Heuristic Rules. 2020 20th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA),.

Adenowo, A.A. and Adenowo, B.A., 2013. Software Engineering Methodologies: A Review of the Waterfall Model and Object-Oriented Approach. International Journal of Scientific & Engineering Research, 4(7), pp.427-434.

Aguado-Delgado, J., Gutierrez-Martinez, J.M., Hilera, J.R., de-Marcos, L. and Otón, S., 2020. Accessibility in video games: a systematic review. Universal Access in the Information Society, 19(1), pp.169-193.

Ahmed, A., Ahmad, S., Ehsan, N., Mirza, E. and Sarwar, S.Z., 2010, June. Agile software development: Impact on productivity and quality. In 2010 IEEE International Conference on Management of Innovation & Technology (pp. 287-291).

BBC News. 2020. Last of Us Part II: Is this the most accessible game ever?. [online] Available at: <https://www.bbc.co.uk/news/technology-53093613> [Accessed 23 February 2022].

Bertolino, A., Fantechi, A., Gnesi, S., Lami, G. and Maccari, A., 2002, September. Use case description of requirements for product lines. In Proceedings of the international workshop on requirements engineering for product lines (pp. 12-19).

Brown, M. and Anderson, S., 2020. Designing for Disability: Evaluating the State of Accessibility Design in Video Games. Games and Culture, 16(6), pp.702-718.

Bucanek, J, 2009. Learn Objective-C for Java Developers, 2009. Model-View-Controller Pattern. pp.353-402.

Bunt, B.J., 2019. Potential benefits of a Puzzle Video Game-Cognitive Enrichment Programme for the development of critical thinking among first year BEd students (Doctoral dissertation, North-West University (South Africa).

Carter, J. and Markel, M., 2001. Web accessibility for people with disabilities: An introduction for web developers. IEEE transactions on professional communication, 44(4), pp.225-233.

Castro, F., Kellison, J., Boyd, S. and Kopak, A., 2010. A Methodology for Conducting Integrative Mixed Methods Research and Data Analyses. Journal of Mixed Methods Research, 4(4), pp.342-360.

Chung, L., Nixon, B.A., Yu, E. and Mylopoulos, J., 2012. Non-functional requirements in software engineering (Vol. 5). Springer Science & Business Media.

Costello, R., Lambert, M. and Kern, F., 2019. How Can Accessibility for Deaf and Hearing-Impaired Players be Improved in Video Games?. International Journal of R&D Innovation Strategy, 1(1), pp.16-32.

Creswell, J., Clark, V.P., Gutmann, M. and Hanson, W.E., 2003. Handbook of mixed methods in social and behavioral research. Tashakkori A, Teddlie C, editors.

Data protection (2022). Available at: https://www.gov.uk/data-protection (Accessed: 5 January 2022)

Docs.unity3d.com. 2022. Quick start guide | Input System | 1.0.2. [online] Available at: <https://docs.unity3d.com/Packages/com.unity.inputsystem@1.0/manual/QuickStartGuide.html> [Accessed 3 May 2022].

EHU Guidance, 2022. Ethics Policy for Undergraduate and Taught Postgraduate Research. [online] Available at: <https://www.edgehill.ac.uk/research/things-to-consider/governance/?tab=ethics-risk> [Accessed 5 May 2022].

Fageha, M. and Aibinu, A., 2013. Managing Project Scope Definition to Improve Stakeholders' Participation and Enhance Project Outcome. Procedia - Social and Behavioral Sciences, 74, pp.154-164.

Federal Communications Commission, 2018. 21st century communications and video accessibility act (CVAA) consumer guide.

Fernández-Sáez, A.M., Chaudron, M.R. and Genero, M., 2013, January. Exploring Costs and Benefits of Using UML on Maintenance: Preliminary Findings of a Case Study in a Large IT Department. In EESSMOD@ MoDELS (pp. 33-42).

Game Accessibility Guidelines. 2022. Game accessibility guidelines | A straightforward reference for inclusive game design. [online] Available at: <https://gameaccessibilityguidelines.com/> [Accessed 2 January 2022].

Hersh, M. and Leporini, B., 2018. Serious games, education and inclusion for disabled people editorial. British Journal of Educational Technology, 49(4), pp.587-595.

Iacono, J., Brown, A. and Holtham, C., 2009. Research methods—A case example of participant observation. Electronic journal of business research methods, 7(1), pp.pp39-46.

Ibm.com. 2022. What is bug tracking? | IBM. [online] Available at: <https://www.ibm.com/topics/bug-tracking> [Accessed 6 May 2022].

Investopedia. 2022. How the Video Game Industry Is Changing. [online] Available at: <https://www.investopedia.com/articles/investing/053115/how-video-game-industry-changing.asp> [Accessed 21 February 2022].

KELLEY, K. (2003) "Good practice in the conduct and reporting of survey research", International Journal for Quality in Health Care, 15(3), pp. 261-266.

Kroll, T. and Neri, M., 2009. Designs for mixed methods research. Mixed methods research for nursing and the health sciences, 31.

Lefever, S., Dal, M. and Matthíasdóttir, Á., 2007. Online data collection in academic research: advantages and limitations. British Journal of Educational Technology, 38(4), pp.574-5

Lindstrom, L. and Jeffries, R., 2003. Extreme programming and agile software development methodologies. In IS management handbook (pp. 531-550). Auerbach Publications.

Litosseliti, L., 2003. Using focus groups in research. A&C Black.

Malan, R. and Bredemeyer, D., 2001. Functional requirements and use cases. Bredemeyer Consulting.

Metalpopgames.com. 2022. UI Accessibility Plugin: Overview. [online] Available at: <http://www.metalpopgames.com/assetstore/accessibility/doc/index.html> [Accessed 30 April 2022].

Pegi Public Site. (2020). What do the labels mean? [online] Available at: https://pegi.info/index.php/what-do-the-labels-mean [Accessed 3 Jan. 2022].

PLUS QA - Web and Mobile Applications QA Testing Company. 2022. Accessibility in the Video Game Industry. [online] Available at: <https://plusqa.com/2021/10/07/accessibility-in-the-video-game-industry/> [Accessed 23 February 2022].

Powers, G., Nguyen, V. and Frieden, L., 2015. Video Game Accessibility: A Legal Approach. Disability Studies Quarterly, 35(1).

Rodríguez, A., Boada, I., Thió-Henestrosa, S. and Sbert, M., 2018. CPRforblind: A video game to introduce cardiopulmonary resuscitation protocol to blind people. British Journal of Educational Technology, 49(4), pp.636-645.

Shrivastava, A., Jaggi, I., Katoch, N., Gupta, D. and Gupta, S., 2021, July. A Systematic Review on Extreme Programming. In Journal of Physics: Conference Series (Vol. 1969, No. 1, p. 012046). IOP Publishing.

Singh, V., 2022. What is Extreme Programming (XP) and its Principles & Practices?. [online] TOOLSQA. Available at: <https://www.toolsqa.com/agile/extreme-programming/> [Accessed 5 May 2022].

Taylor, Z.W., 2018. Web accessibility: Not just for tech experts anymore. Disability Compliance for Higher Education, 23(9), pp.5-5.

UCLA. 2022. Pretest a Survey Questionnaire. [online] Available at: <https://ctsi.ucla.edu/patients-community/files/view/docs/Howto_pretest_survey_questionnaire.pdf> [Accessed 6 May 2022].

Unity. (2021). Can I use assets from the Asset Store in my commercial game? [online] Available at: https://support.unity.com/hc/en-us/articles/205623589-Can-I-use-assets-from-the-Asset-Store-in-my-commercial-game- [Accessed 3 Jan. 2022].

Wiederhold, B., 2021. Kids Will Find a Way: The Benefits of Social Video Games. Cyberpsychology, Behavior, and Social Networking, 24(4), pp.213-214.

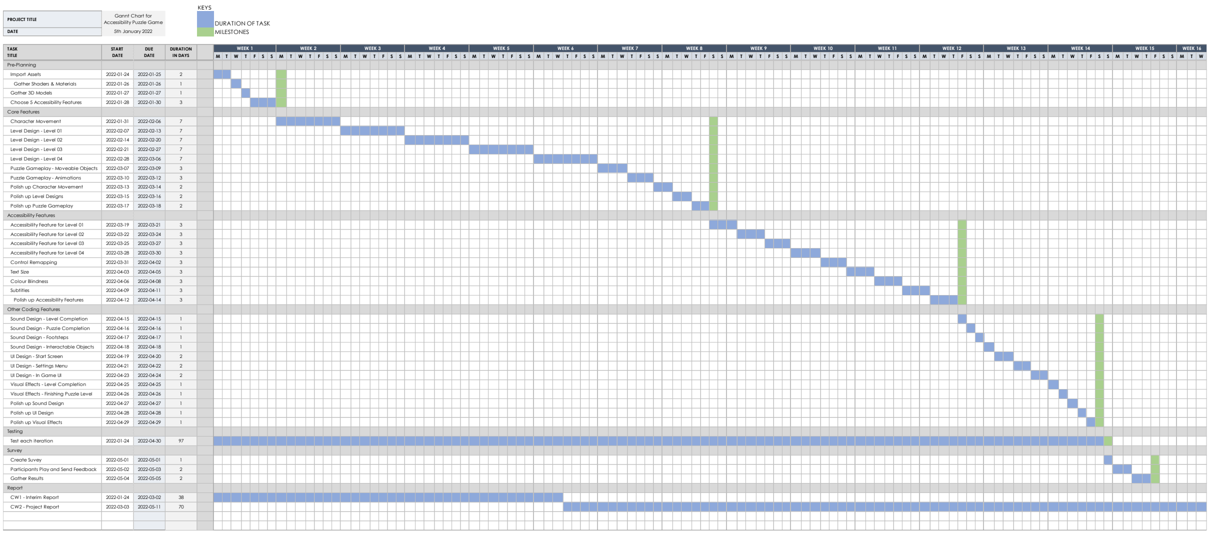
Wilson, A. and Crabb, M. (2018) "W3C Accessibility Guidelines for Mobile Games", The Computer Games Journal, 7(2), pp. 49-61.

World Health Organization, 2011. World report on disability. Geneva: World Health Organization.

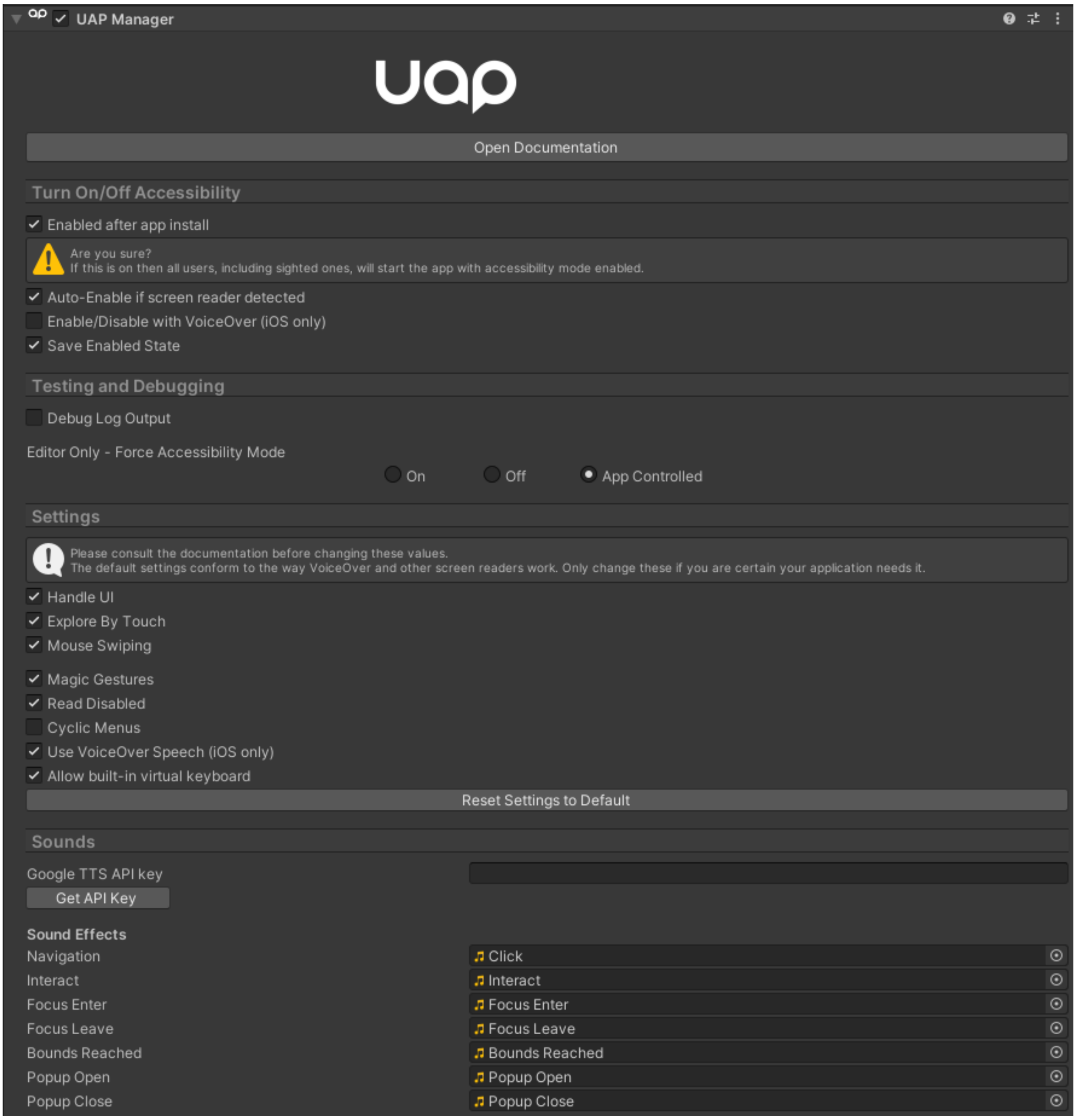
Yuan, B., Folmer, E. and Harris, F.C., 2011. Game accessibility: a survey. Universal Access in the information Society, 10(1), pp.81-100.

Appendices

Appendix 01 - Project Plan



Appendix 02 – The UAP Accessibility Manager in Unity



Appendix 03 – The Trello Board

https://trello.com/b/FEZStNLL/project-plan

Appendix 04 – Functional Requirements Table

Functional Requirements	Priority
Basics	
The system will be run using the Unity Engine	1
The system will use assets from the Unity store	1
The system will allow a user to control the character controller.	1
The system will allow a user to select a level to play.	1
The system will allow a user to change the settings of the game.	1
The system will allow a user to read the instructions of the game.	1
The system will allow a user to exit the game.	1
Accessibility	
The system will have visual accessibility features within the game	1
The system will have cognitive accessibility features within the game	1
The system will have hearing accessibility features within the game	1
The system will have motor accessibility features within the game	1
The system will allow a user to turn on/off accessibility features	2
The system will include screen reader functionalities	1
In-Game	
The system will allow a user to interact with objects (doors, boxes, code panels)	2
The system will allow for lighting effects	2
The system will allow for visual effects	2
The system will allow a user to type in a keycode	1
The system will detect if the keycode is correct or incorrect.	2
The system will allow a user to pick up a keycode	1
The system will allow a user to pause the game	3
The system will be able to detect if the player character is grounded.	3
The system will provide a completion time when the level is complete.	4
In-Game UI	
The system will provide UI text to inform the user of the keycode once picked up.	1
The system will provide UI text to inform the user they can interact with an object.	1
The system will provide UI text to inform the user they have completed the level.	3
The system will provide UI text to inform the user they have paused the game	3
The system will allow a user to change the settings of the game from the pause menu	3

The system will allow a user to return to the main menu from the pause menu	3
The system will allow a user to continue playing the game from the pause menu	3
Collisions and Triggers	
The system will be able to detect a collision between the player character and an interactable object.	2
The system will prevent the player character from going through objects	4

Appendix 05 – Non-Functional Requirements Table

Non-Functional Requirements	**Description**	**How to Check Requirements**
Framerate	The minimum frame rate must be thirty frames per second or greater. This is to achieve the normal performance of the game	The frame rate can be monitored directly in-game from the graphic engine.
Usability	The maximum number of clicks for any function or interaction in the system should not exceed two clicks.	This can be achieved with usability tests.
Response Time	The average response time between click and reaction must be less than one second. Any response time higher than two seconds must be fixed accordingly.	This can be achieved by implementing methods within the code to display the time of response.
Required Resources	The game must be run with a minimum of 2GB of RAM to ensure good performance. An allocated amount of 1GB of hard disk space is required to install the game.	Windows Task Manager will display the total RAM used. Checking the total size of the folder where the game is installed.
Platform	The game must be run on Windows.	Installing the game in Windows and ensuring the game runs correctly.
Accessibility	The game must be made accessible for all users.	The survey results will dictate if any part of the game is unplayable.

Appendix 06 – Requirement Checking for Framerate

Appendix 07 – Requirement Checking for Usability

Game Output:	Text to Speech
Inputs:	Arrow Keys
Steps:	1) Hover over a UI Element
Success Criteria:	Audio sound outputs text value (see Figure 3)

Game Output:	Hot and Cold Meter (Level 02)
Inputs:	Move Character
Steps:	1) Move Character 2) Check Hot and Cold Meter
Success Criteria:	The meter gets colder or hotter depending on the player distance from the key (see Figures 5 and 6)

Game Output:	Enable Arrow (Level 03)
Inputs:	C Key
Steps:	1) Press C Key
Success Criteria:	The arrow should be pointing toward the key object (see Figures 7 and 9)

Game Output:	Screen Reader Navigation
Inputs:	Arrow Keys
Steps:	1) Use up and down arrow keys to control the User Interface
Success Criteria:	Different UI elements should be selected (see Figure 11)

Game Output:	Remember keycode message
Inputs:	E Key
Steps:	1) Find the keycode 2) Interact with keycode (E key) 3) Close keycode UI
Success Criteria:	Remember message should show the keycode number on the screen (see Figure 13).

Appendix 08 – Requirement Checking for Response Time

Input	**Response Time (in milliseconds)**
Character Movement	13ms
Button Click	30ms
Interact Button	24ms
Pause Button	13ms
Enable Arrow	13ms

Appendix 09 – Requirement Checking for Required Resources

Highest recorded memory usage – Accessibility turned on, with all sounds enabled, within Level 04 of the game.

Name	Status	58% CPU	43% Memory
R&D Project.exe (2)		45.1%	196.7 MB

Lowest recorded memory usage – Accessibility turned off, no sound, on the main menu

Name	Status	CPU	Memory
Desktop Window Manager		6.2%	35.2 MB
R&D Project.exe (2)		5.6%	133.5 MB

The required amount of hard disk space to play the game.

R&D Project	
Type:	File folder
Location:	D:\Coding Things
Size:	0.98 GB (1,058,038,830 bytes)
Size on disk:	0.98 GB (1,058,353,152 bytes)
Contains:	174 Files, 16 Folders

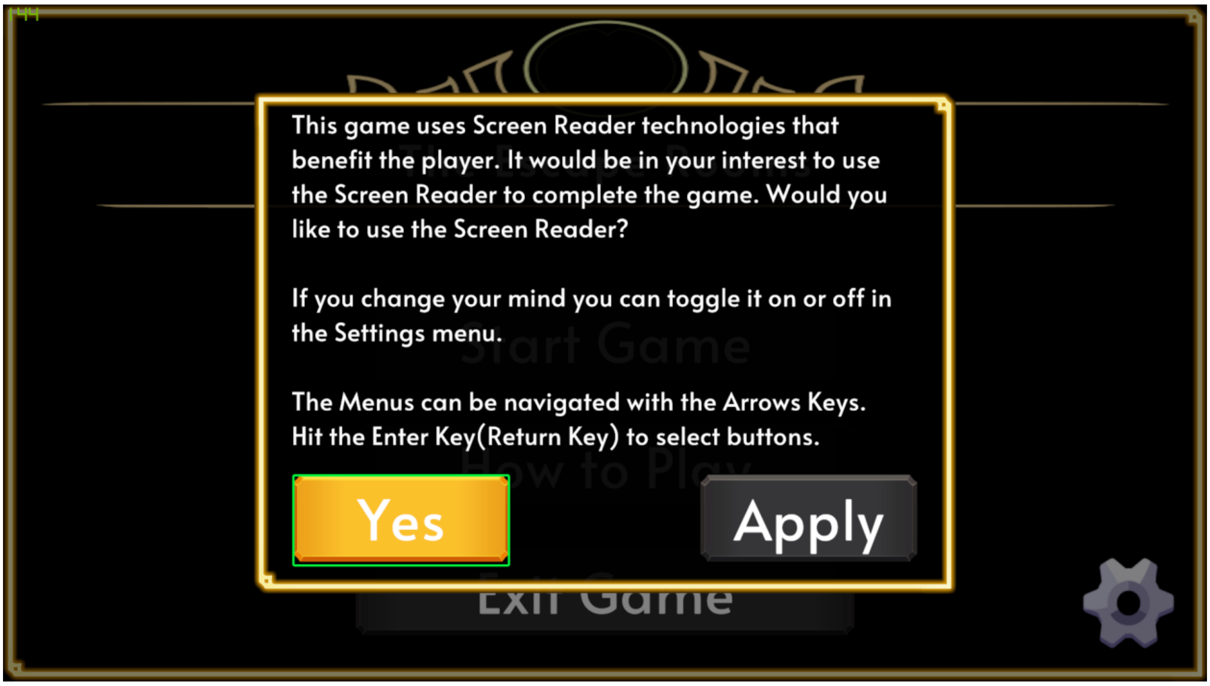
Appendix 10 – Requirement Checking for Installed Files

Files installed correctly onto Windows computer.

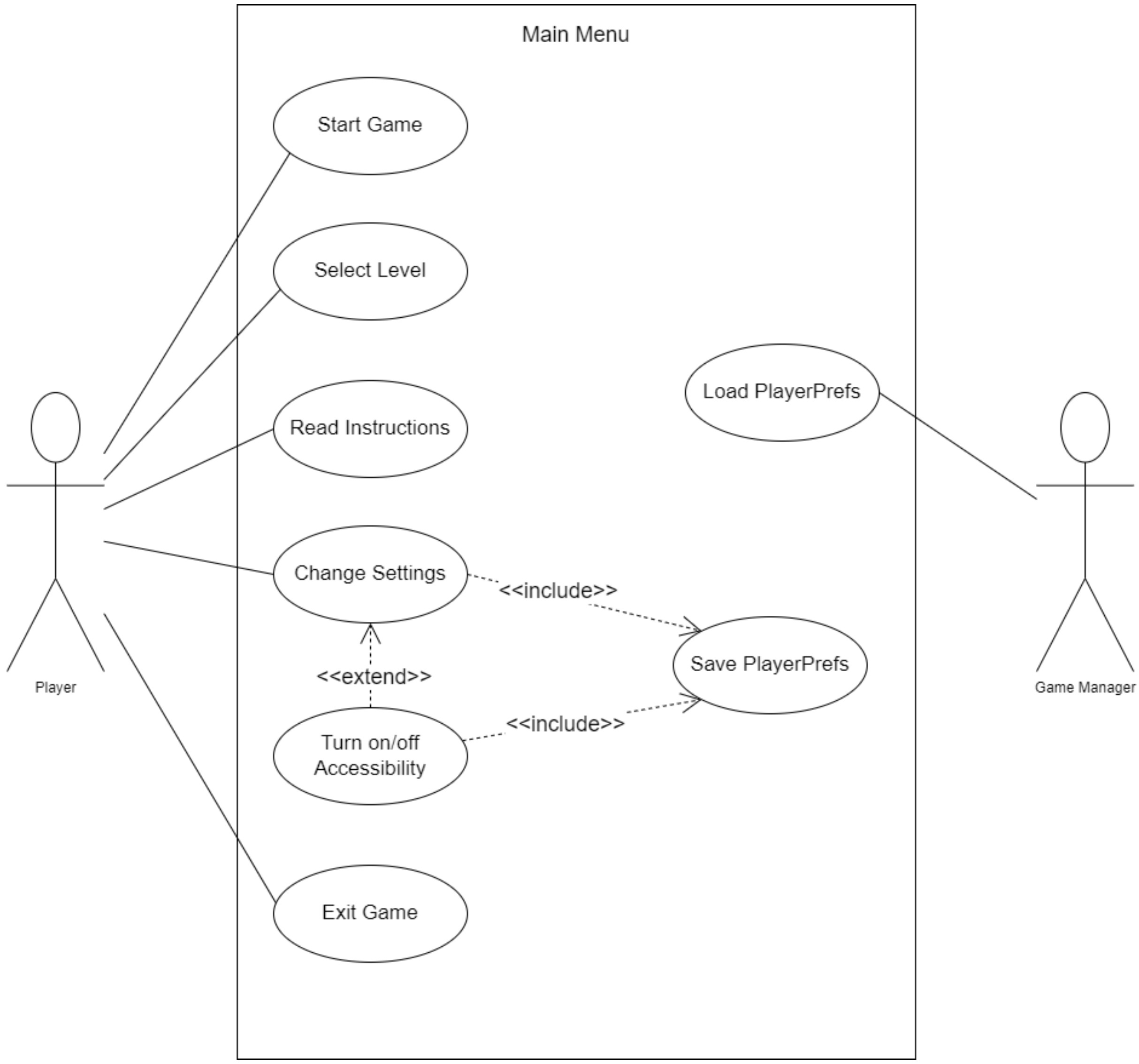
MonoBleedingEdge	13/04/2022 00:06	File folder	
R&D Project_Data	13/04/2022 00:06	File folder	
R&D Project.exe	26/01/2022 23:44	Application	639 KB
UnityCrashHandler64.exe	26/01/2022 23:45	Application	1,205 KB
UnityPlayer.dll	26/01/2022 23:45	Application exten...	27,574 KB

Appendix 11 – Requirement Checking Game Runs as Intended

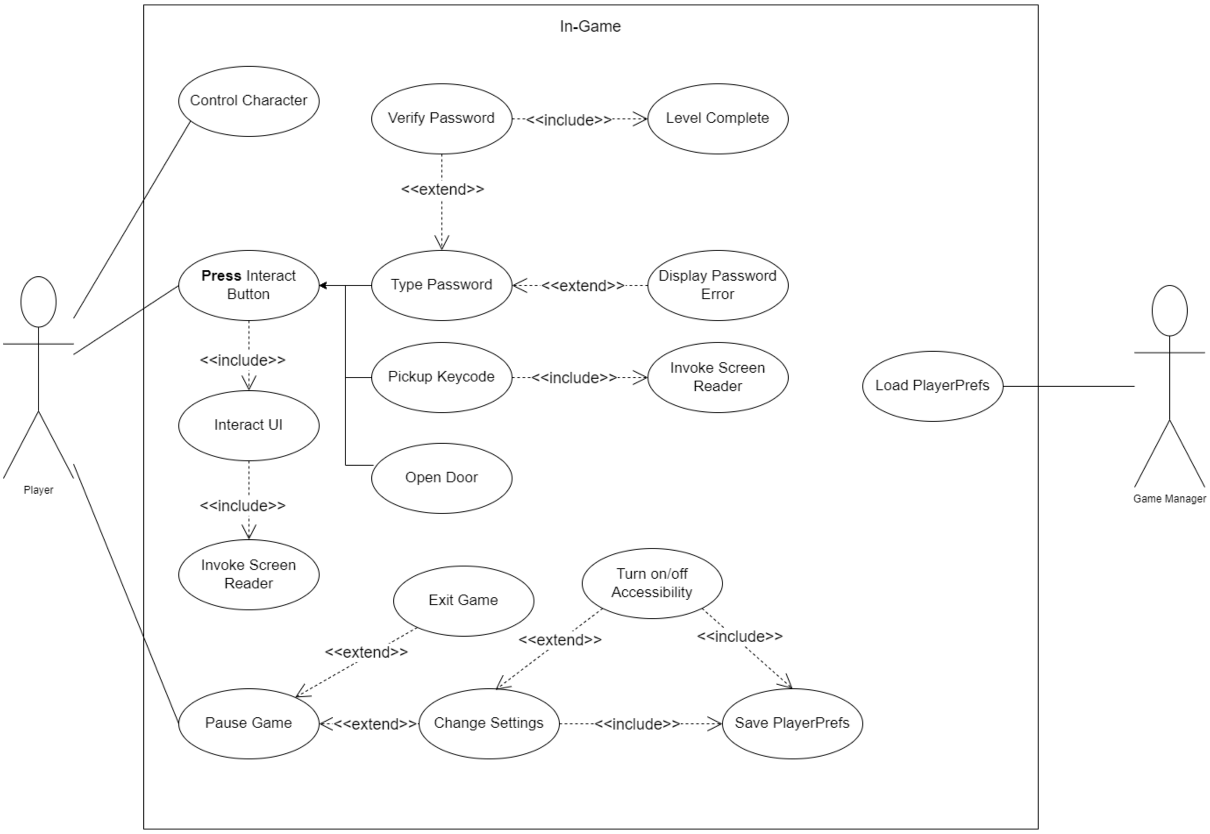
The game runs as intended on a Windows computer.



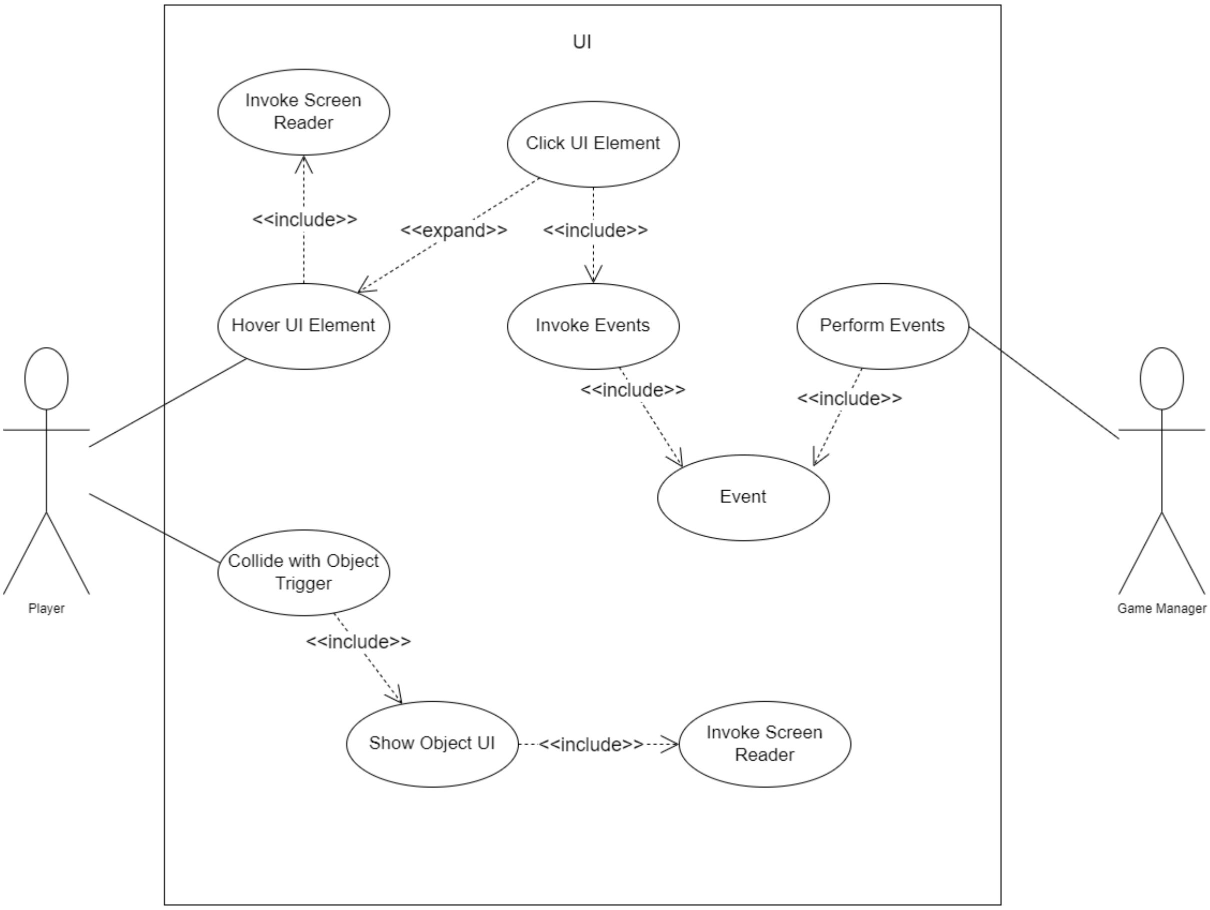
Appendix 12 – Menu Use Case Final Design



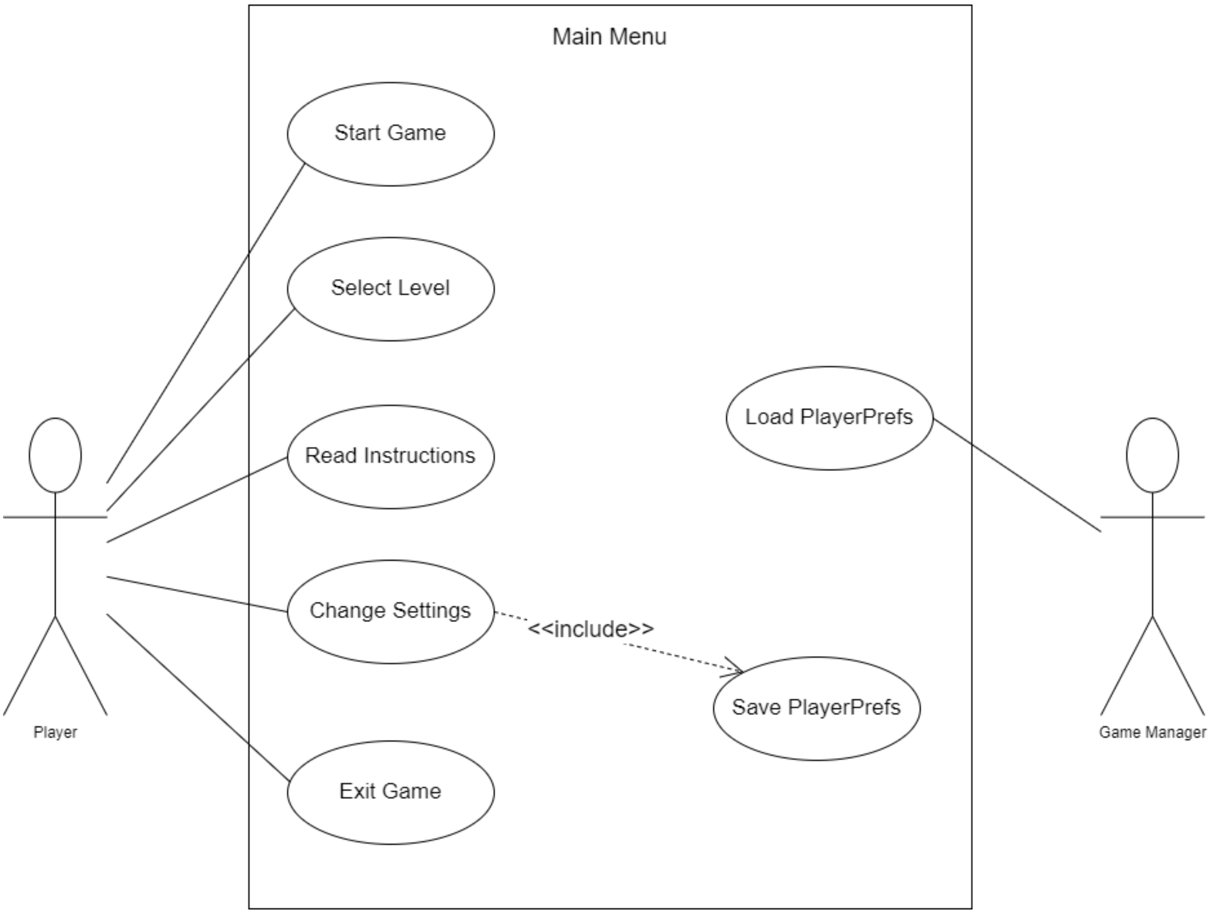
Appendix 13 – In-Game Use Case Final Design



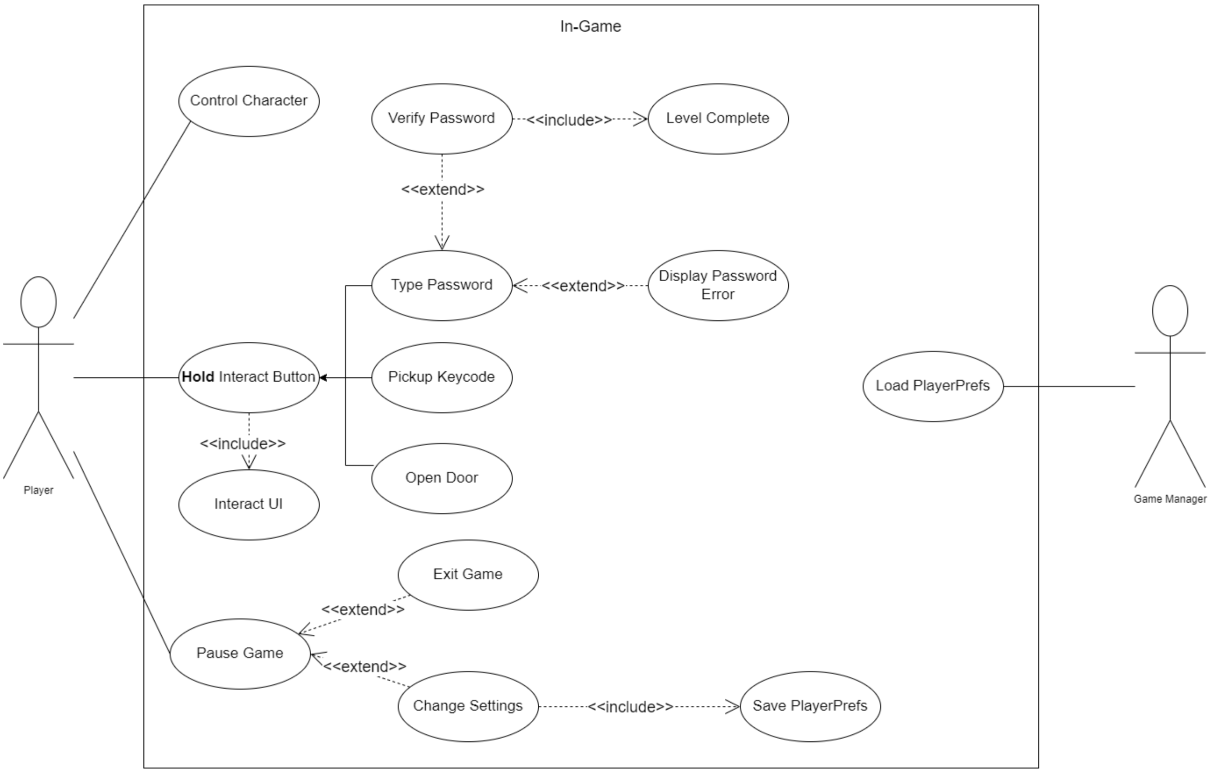
Appendix 14 – UI Use Case Final Design



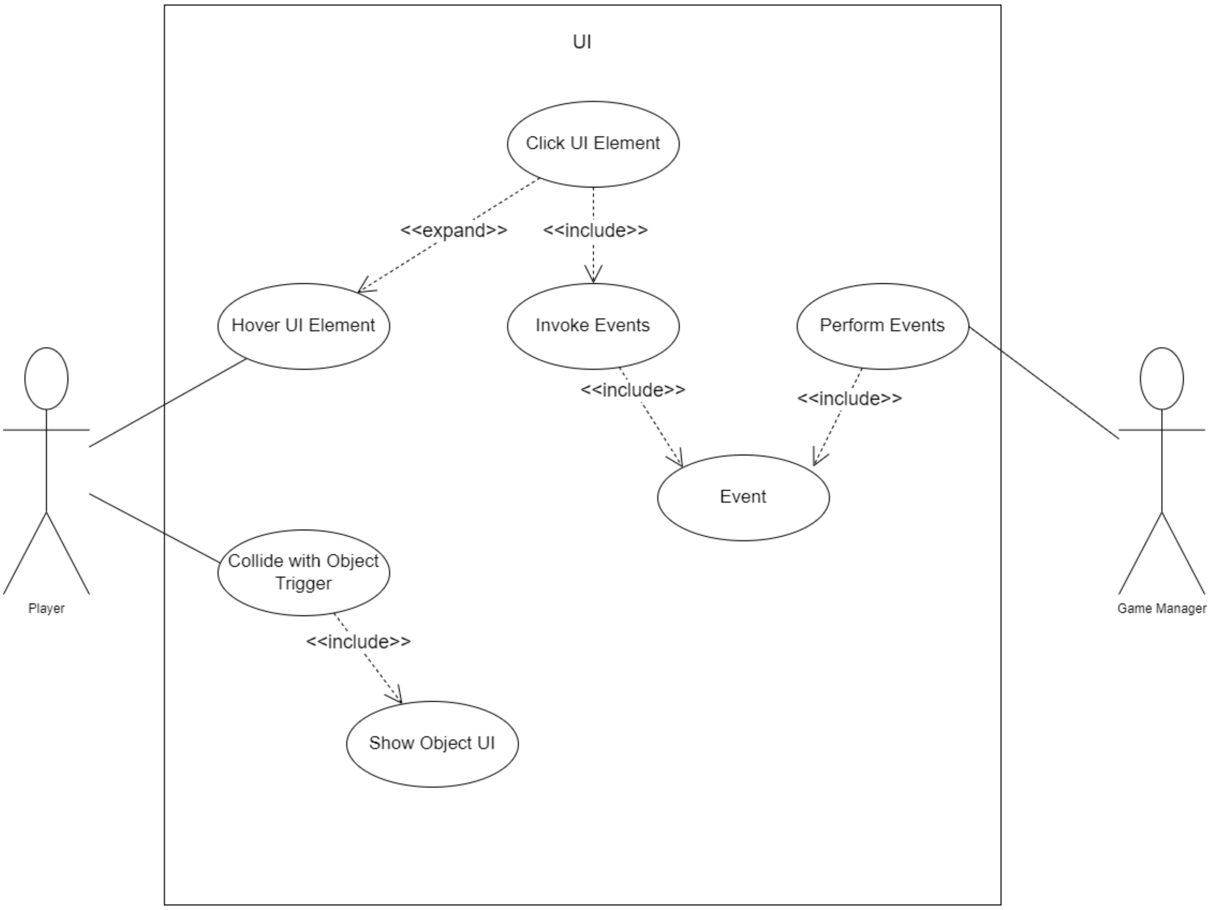
Appendix 15 – Menu Use Case Alternate Design



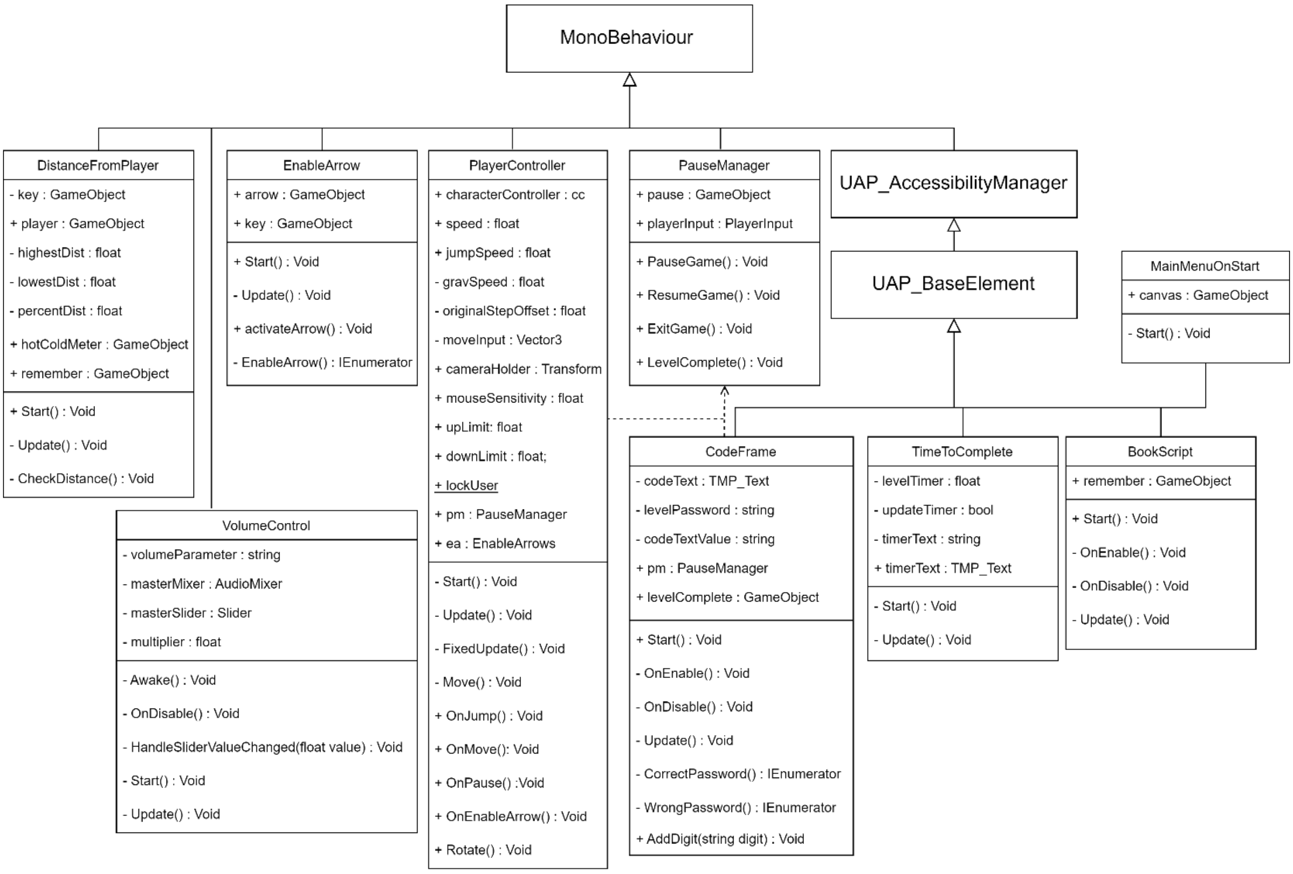
Appendix 16 – In-Game Use Case Alternate Design



Appendix 17 – UI Use Case Alternate Design



Appendix 18 – The Class Diagram



Appendix 19 – Survey Document

1. Please Read

Progress

0%

This survey is being conducted by Daniel Bresnahan at Edge Hill University.

The following survey is being conducted to collect data involving the Escape Room puzzle game. It is important that you have first played the game with accessibility features turned on before completing the survey.

The goal of the survey will be to generate feedback from the participants, this feedback can then be used to support the overall aim of the project.

There will be 10 survey questions, followed by 4 pre-testing questions. There is no time limit, however it should take no longer than 10 minutes.

The timeframe for the survey completion is 30th April 2022 at 11:59am.

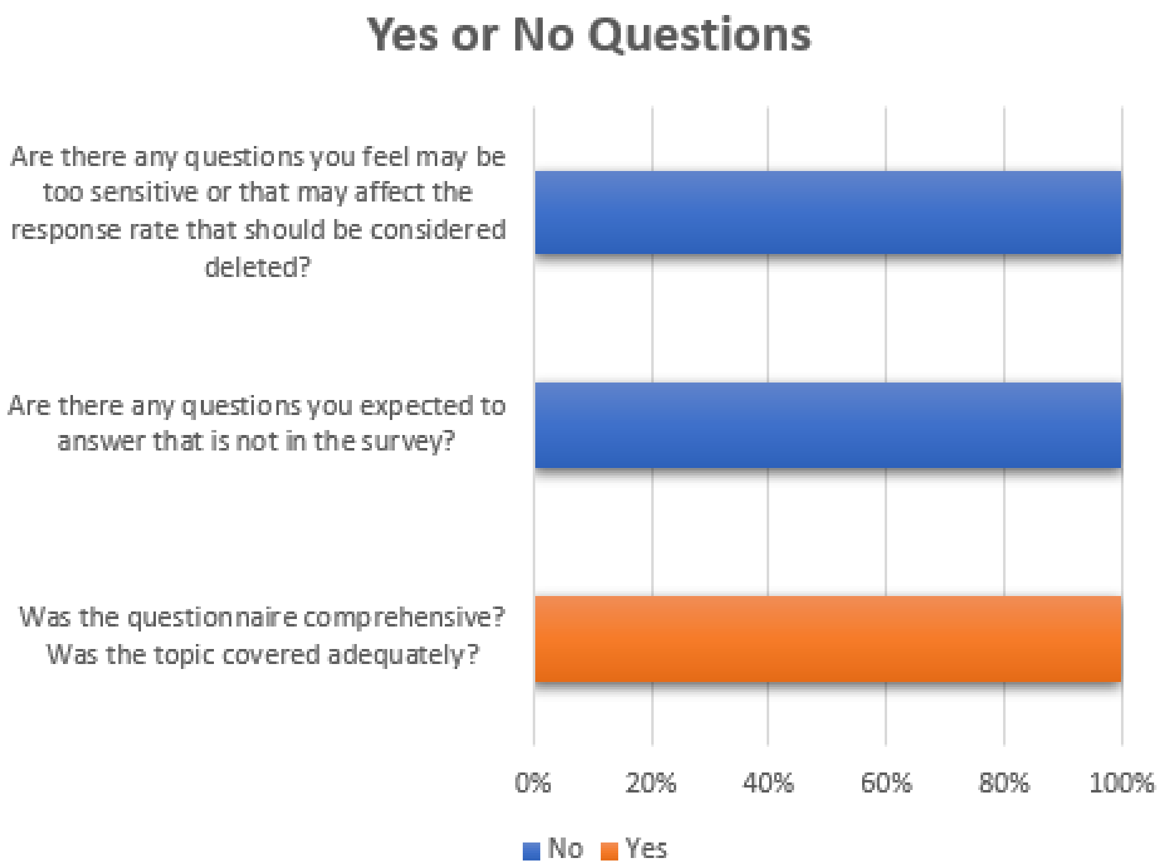
If you would like to withdraw from the survey you can;

1. Exit the survey at any time.
2. If you have completed the survey and would like your data removed, please contact me at the below email address.

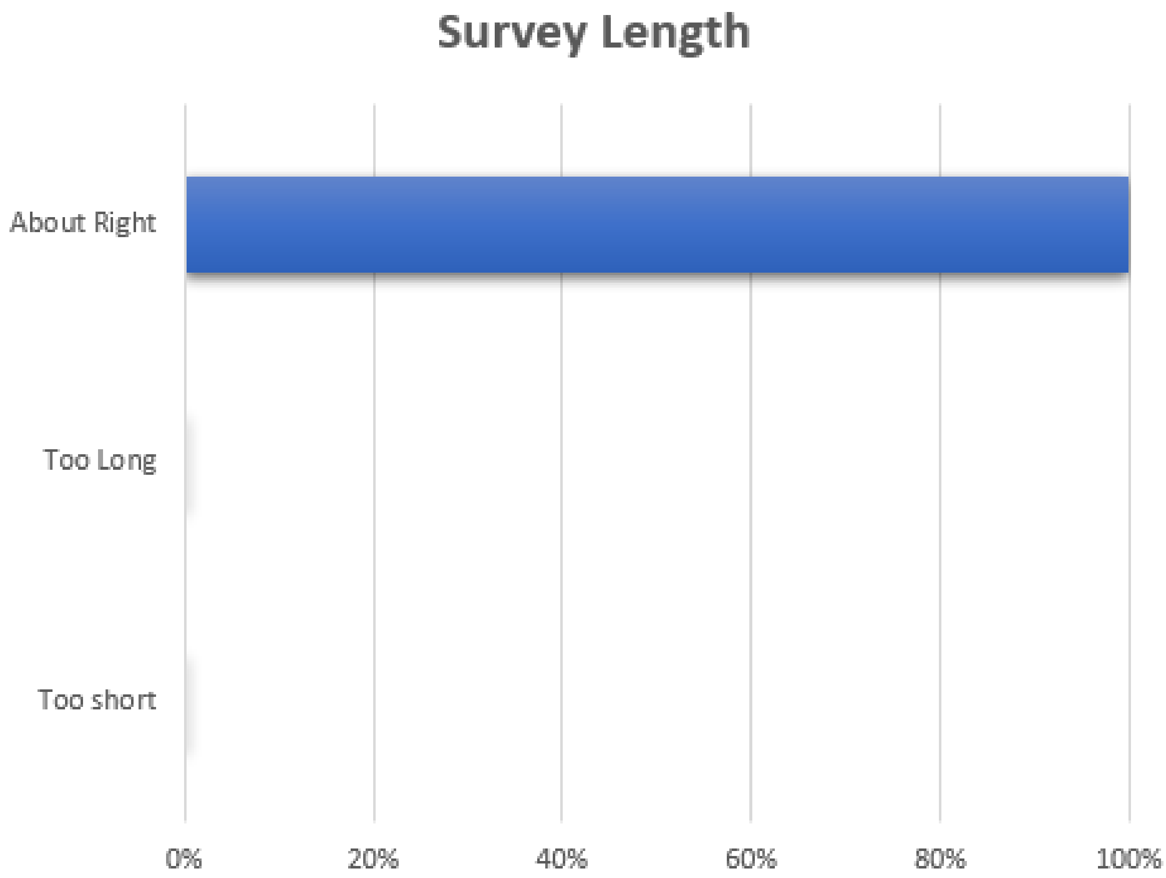
For further information please contact me at 24361071@edgehill.ac.uk

Next Page

Appendix 20 – Pretest Survey, Yes or No Questions



Appendix 21 – Pretest Survey, Survey Length Question



Appendix 22 – Survey's Quantitative Data

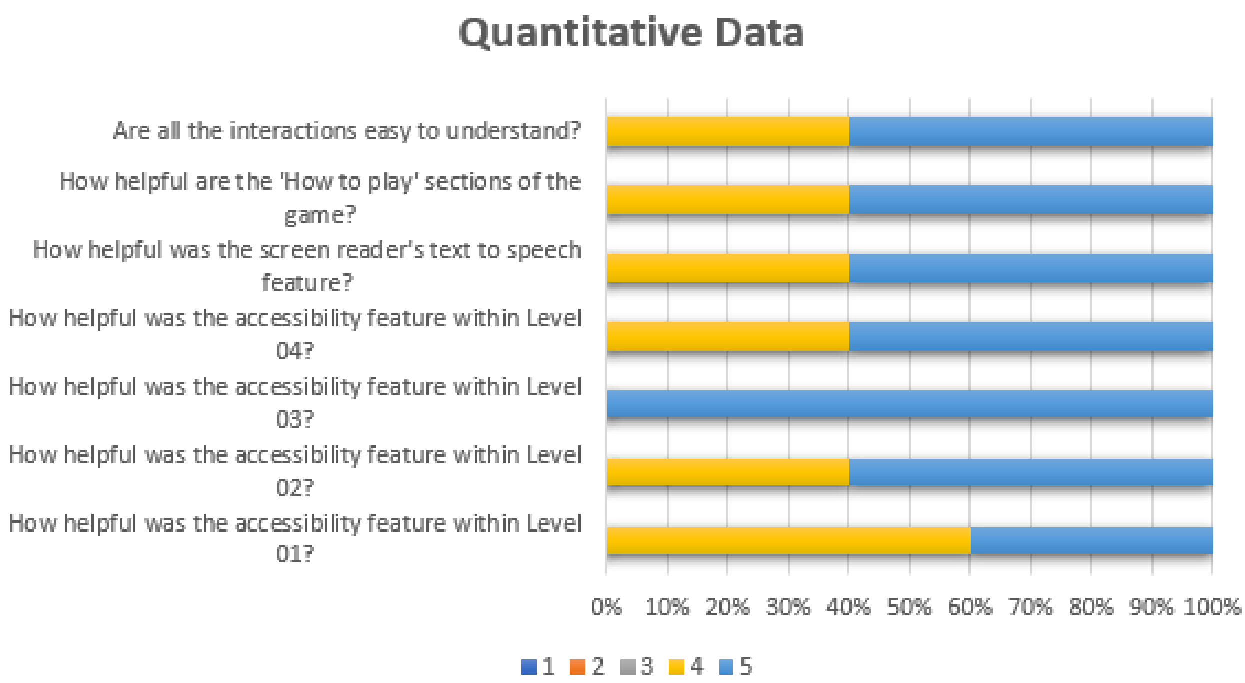
1 = Not at all helpful/clear

2 = Not so helpful/clear

3 = Somewhat helpful/clear

4 = Very helpful/clear

5 = Extremely helpful/clear



Appendix 23 – Artefact YouTube Video

https://youtu.be/DRnS-dhrzn8

Appendix 24 – Participant Information Sheet

Participant information sheet

Study title

Evaluation and Development of Accessibility Features Within Video Games

Principal researcher

Researcher: Daniel Bresnahan

Researchers Email: 24361071@edgehill.ac.uk

Supervisor: Mark Liptrott

Supervisors Email:liptrotm@edgehill.ac.uk

Invitation

You are invited to participate in a study about accessibility within video games. This research is being completed to provide data relevant to the aim of the project. This will involve playing the created game by the researcher and taking part in a survey once the game is complete.

Please take the time to read through the information which follows carefully and discuss it with others if you wish. If you would like more information or anything is unclear, feel free to inform the researcher

What is the purpose of the study?

The project aims to create a game that provides players with equal access by implementing accessibility features. This research hopes to encourage the implementation of accessibility features as it provides equal access. By having equal access, people with disabilities can enjoy video games like everyone else.

Why have I been invited?

Participants who are invited will have experience playing video games. Their knowledge of this topic will be required to acknowledge and interpret the accessibility features that have been implemented.

Consent

Participation in this study is voluntary and can be withdrawn at any point. If you wish to no longer take part in the study, you can withdraw with the safe word which you will create at the end of the survey.

The only information that will be used is your answers based on your experience with the game and that you are a student at Edge Hill University who has played games in the past.

Data protection legislation & the lawful basis for processing personal data

The General Data Protection Regulation (GDPR) operates in parallel to various other pieces of data protection legislation and updates, and expands people's rights to see, correct and, normally, delete their *personal* data that is held by an organisation. It, therefore, places additional legal responsibility on the researcher.

As a result, the University is committed to ensuring compliance with current data protection legislation and confirms that all data collected is used fairly, stored safely, and not disclosed to any other person unlawfully. The University is a data controller and, in some instances, maybe a data processor of this data.

How Can I withdraw consent?

To withdraw consent, you will provide a safe word which you set at the end of the survey. Any data that has been collected from the participant will be deleted upon request. Any form of anonymous data cannot be withdrawn as the participant cannot be identified.

Will my participation be confidential?

All participant data will comply with the Data Protection Act 2018. Through this compliance, all data regarding names, contact details, etc will be protected and safely stored using encrypted passwords.

What will happen to the results of the research study?

The data will be used to develop evidence regarding the aim of the project. Data that is collected with both be qualitative and quantitative. Any qualitative data will be placed in table format to distinguish the positive and negative open-ended feedback. Any quantitative data will be used to develop graphs that show the ratings each question received.

Data that is published on the project will be there indefinitely, as this data is important to the aim of the project. However, this will all be published anonymously as the data shows no form of details that leads back to the participant.

What will I be asked to do?

Participants will be asked to complete the puzzle game. This involves completing all four levels within the game. Depending on how long it takes to complete each level, this could take anywhere between 10-15 minutes.

After the game is complete, participants are asked to complete a survey. This involves answering 10 questions regarding the accessibility features of the game they played. This should take 5-8 minutes to complete.

What are the possible benefits of taking part?

Participants that have taken part in this study may come out of it with a better understanding of accessibility. They might also have a better understanding of the limitations some people have while playing video games.

Final Consent

Participants that agree with the above information and want to participate in this study will need to fill out the Participant Consent Form. This would have been provided along with the Participant Information Sheet.

Appendix 25 – Participant Consent Form

Participant Consent Form

Project title: Evaluation and Development of Accessibility Features Within Video Games

Researcher: Daniel Bresnahan

- I confirm that I have read and understand the information sheet for the above study ☐
- I have been given the opportunity to ask questions ☐
- I agree to take part in this study ☐
- I understand that my participation is voluntary and that I am free to withdraw for up to four weeks after the date of the consent. ☐

Name of participant ……………………………………………………………………

Signature ……………………………………………………………………….

Date ……………………………………………………………………….

Researcher ……………………………………………………………………….

Signature ……………………………………………………………………….

Date ……………………………………………………………………….

Appendix 26 – Self Assessment Checklist

If your research involves human participants, are any of the following concerns relevant?	
No	1. The involvement of vulnerable participants or groups, such as children (under the age of 16), people with a learning disability or cognitive impairment, or persons in a dependent relationship?
No	2. The sensitivity of the research topic, e.g. the participants' sexual, political, or legal behaviour, or their experience of violence, abuse or exploitation?
No	3. The gender, ethnicity, language, or cultural status of participants?
No	4. The use of deception, trickery, or other procedures that may contravene participants' full or informed consent, without timely and appropriate debriefing, or activities that cause stress, humiliation, or anxiety, or the infliction of more than minimal pain?
No	5. Access to records of personal or other confidential information, including genetic or other biological information, concerning identifiable individuals without their knowledge or consent?
No	6. The use of intrusive interventions, such as the administration of drugs or other treatments, excessive physical exertion, or techniques such as hypnotherapy without the participants' knowledge or consent?
No	7. Research related to the NHS is strongly advised to seek advice from their supervisor before commencing the project

Approval for Low Risk Research Projects

I can confirm that : ***(confirm you have read these)***

- **I have read the Edge Hill University Framework for Research Ethics** **http://www.edgehill.ac.uk/research/research-ethics-governance/**
- **I have read the Computing Departments Ethics Policy Document (see BB).**
- **I agree to abide by their principles**

Student	Daniel Bresnahan
Date:	03rd January 2022
Supervisor	Peter Vangorp
Module leader	Ella Pereira

Appendix 27 – Project Management Scope

Project Name

Evaluation and Development of Accessibility Features Within Video Games

Project Objective

Build a puzzle game using accessibility features that provide equal access to all players. Provide research evidence on the importance of accessibility features.

Deliverables

- A fully built and working puzzle game using the Unity Engine.
- Research evidence stating the importance of accessibility.
- Collection of Survey data.

Project Requirements

- The game must include basic features such as character movement and interaction.
- Players must have the option to turn accessibility features on and off.
- Accessibility features must provide equal access to those that need them.
- The project must implement support for visual, motor, cognitive and hearing impairments.
- Collection of data from participants of the game is required for evidence.

Milestones

1. Pre-planning____due by 30th January 2022.
2. Core Features____due by 18th March 2022.
3. Accessibility Features ___________________________________due by 14th April 2022.
4. Remaining Features_____________________________________due by 29th April 2022.
5. Testing____due by 30th April 2022.
6. Survey and Survey Results________________________________due by 5th May 2022.
7. Project Report_______________________________________due by 11th May 2022.

Project Acceptance Criteria

- Successfully built a puzzle game with implemented accessibility features.
- Received feedback addressing the project's aim in the form of survey data.

Project Constraints

- The game must be built and fully tested before 30th April so that the survey can begin.
- Survey data retrieved from participants must be collected by the 5th of May.
- The Project Report must be completed by 11th May.