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Games for children with learning disabilities

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Statement of integrity

I declare that this **project work** is the result of my personal and independent research. Its content is original, and all sources listed in the bibliographic references were consulted and are duly mentioned in the text. I further declare that all scientific and technical references relevant to the development of the work are duly cited and included in the bibliographic references.

The author

Lisbon, ... , ...

Abstract

The purpose of this thesis is the development and evaluation of five educational mini-games designed for children with learning disabilities. The main objective is to create a fun and accessible way to support children overcoming different learning disabilities.

Firstly, the development process approaches the theory behind the subject, performing a deep dive to find out what makes a learning disability. This is followed by a complete user profile that aims to detail each learning disability. This research is crucial for success in the creation process.

The implementation comes next. Gameplay requirements for the games are drawn and refined, allowing for the designing of the mockups of each game. Each games will then go through rounds of discussions to better expand the user experience of the children.

The games are then tested with children and results are gathered by both observing and interviewing them. The feedback can then be used as an input for some more implementations. Doing this in a cycle surely creates an even better experience and expanding of the product, overcoming their learning disabilities.

The key findings showed that the children are generally excited about playing the games. However, issues like complicated controls and unclear instructions make things harder for some of them. Despite these problems, the positive feedback suggested that the games managed to keep the children interested and could be helpful for learning.

Keywords: accessibility, accessible learning, child education, cognitive challenges, educational mini-games, game-based learning, gameplay design, iterative development, learning disabilities, user experience, user feedback

Resumo

O objetivo deste projeto é o desenvolvimento e a avaliação de cinco mini-jogos educativos concebidos para crianças com dificuldades de aprendizagem. O principal objetivo é criar uma forma divertida e acessível de apoiar as crianças a ultrapassar diferentes dificuldades de aprendizagem.

Em primeiro lugar, o processo de desenvolvimento aborda a teoria subjacente ao tema, efetuando uma extensa pesquisa para descobrir o que constitui uma perturbação da aprendizagem. Segue-se um perfil de utilizador que visa detalhar cada uma. Esta investigação é crucial para o sucesso do processo de desenvolvimento.

A implementação vem a seguir. Os requisitos de jogabilidade para os jogos são desenhados e refinados, permitindo a conceção de mockups para cada jogo. Cada jogo irá depois ser submetido a rondas de discussão para melhor expandir a experiência de utilização das crianças.

Os jogos são então testados com crianças e os resultados são recolhidos através da observação e de entrevistas com as crianças. O feedback pode então ser utilizado como um contributo para mais algumas implementações. Fazer isto num ciclo cria certamente uma experiência ainda melhor e uma possível expansão no desenvolvimento do produto.

As principais conclusões revelam que as crianças estão geralmente entusiasmadas com os jogos. No entanto, questões como controlos complicados e instruções pouco claras tornam as coisas mais difíceis para algumas delas. Apesar destes problemas, as reações positivas sugerem que os jogos conseguiram manter as crianças interessadas e podem ser extremamente úteis, ultrapassando as suas dificuldades de aprendizagem.

Palavras-chave: acessibilidade, aprendizagem acessível, aprendizagem baseada em jogos, conceção de jogos, desafios cognitivos, desenvolvimento iterativo, dificuldades de aprendizagem, educação de crianças, experiência de utilizador, feedback de utilizador, mini-jogos educativos

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Acronyms

APD	Auditory Processing Disorder 22, 23, 25
GBL	Game Based Learning 6
LD	Learning Disability 6, 27, 28, 57, 58, 65, 66
LPD	Language Processing Disorder 6, 10, 11
NVLD	Non-verbal learning disabilities 16, 17
OOP	Object-Oriented Programming 44, 45, 65, 66
UI	User Interface 3, 43, 48, 49, 54, 55, 63
UML	Unified Modeling Language xiii, 48, 49, 50, 51, 52, 53, 54

1 Introduction

1.1 Motivation and Context

Learning disabilities affect millions of children in the whole world, making it hard for them to get to their full potential. Those disabilities can make the reading comprehension, information memorization, mathematic processes, and the ability to focus on class way harder.

However, technology and games can offer new opportunities to help children with learning disabilities to overcome their challenges. Interactive educational mini games can be projected to teach specific learning abilities in a charismatic and enthusiastic way, while at the same time the players can have a fun and feel accomplishment.

1.2 Thesis Goals

The goal of this project is to explore the potential of educational games to children with learning disabilities. We address the development of mini games having in consideration effective pedagogical approaches, adapted to meet the individual needs of each child. The games will be designed to be accessible and intuitive, providing an environment of growth and motivation.

Lastly, this research hopes to contribute to innovative technological solutions which can improve the quality of life of children with learning disabilities, offering them new opportunities to learn, grow, and achieve their full potential.

Developing a game for children with learning disabilities is a challenging but rewarding project, as it has a positive impact on their learning and development. The focus of this project is to create an engaging and interactive series of mini-games that are tailored to the specific needs of children with learning disabilities, helping them to develop cognitive, social, and motor skills.

Technology can play a crucial role in the development of such games, as it offers many features that can make learning more accessible and enjoyable for children with disabilities. For instance, technologies like touchscreens, motion sensors, and voice recognition can

make the game more interactive, allowing children to use a range of different skills to play and learn.

Moreover, technology can also provide real-time learning feedback, meaning that the game can adjust its difficulty level based on the child's performance, providing targeted support for their individual learning needs. This can help to ensure that the child is always challenged but not overwhelmed, making the game both enjoyable and beneficial.

Overall, developing a game for children with learning disabilities using technology can be an exciting and innovative way to support their learning and development. The project has the potential to contribute to the field of assistive technology and special education and can offer valuable insights into how technology can be used to enhance learning and support the needs of children with disabilities.

1.3 Solution Outline

Figure 1.1 illustrates the solution outline of the project, representing an overview of the solution proposed for the development of this project.

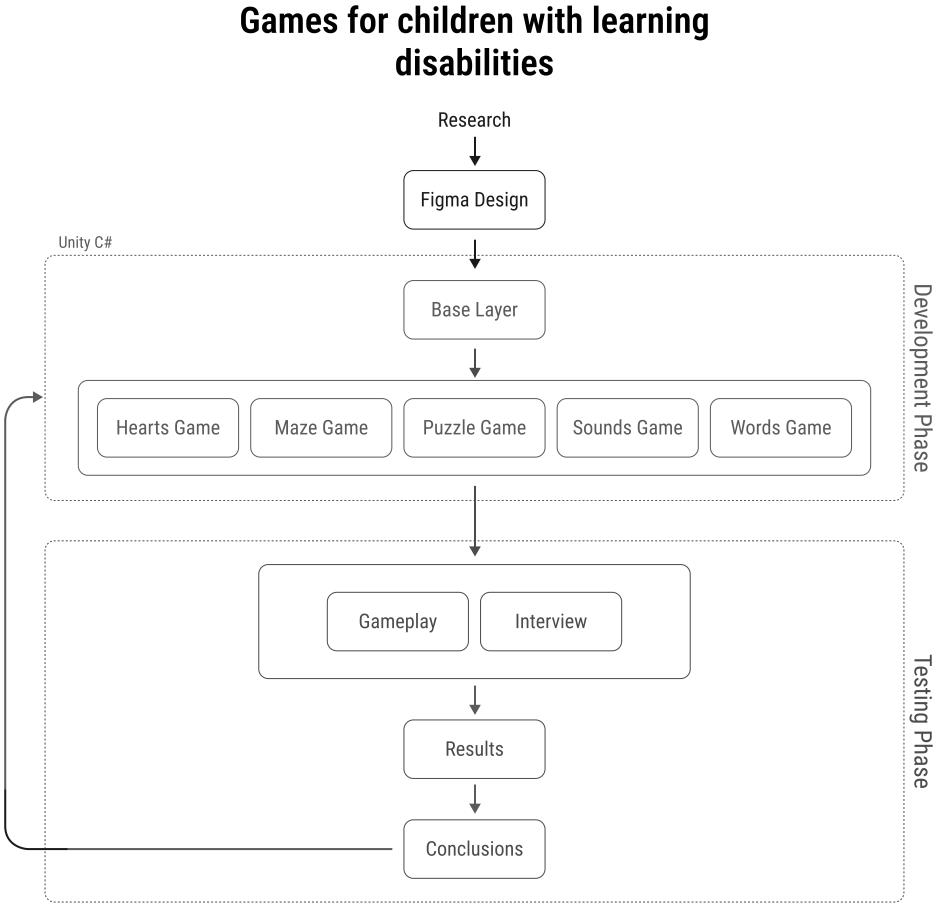

Figure 1.1: *Solution Outline*

The project kicks off with the **research** process, to gather as much information as possible. In this case we're looking at the definition of a Learning Disability and each one's needs. This is followed by the **Figma Design** which is important to detail the games User Interface (UI).

After this, the **development phase** begins, with the creation of the architecture. A base layer is proposed to support all the logic of the games that are built on top. Unity game engine was used in this phase, together with the C# programming language. This is relevant as it allows us to abstract from the device to be deployed on (smartphone, tablet, pc), and focus solely on the development.

Finally, the **testing phase** begins, with a gameplay followed by a small interview for the children. The output from this, are the results, that after careful examination generate conclusion, which will then generate an increment that can directly influence the games ongoing development. The development of the games is an iterative process, meaning as time goes on, there will always be room for improvement, hence why the need for a thoughtful architecture, that can easily support new features and facilitate the development.

1.4 Document Organization

This thesis guides you through the development of educational mini-games designed for children with learning disabilities. Here's how the document is laid out:

1. Introduction Starts by discussing the motivation and context behind this project. An outline of the goals will be observed aiming to achieve and provide an overview of the proposed solution.

2. Related Work In this chapter, a definition of learning disabilities is created and each type will be explored in detail followed by a market research of existing work related to understand what's already available and how this project can contribute.

3. Game Design and Mechanics Here, all the five mini-games are detailed: Hearts, Maze, Sounds, Words, and Puzzle. For each game, we will discuss the specific skills they target and explain how they're designed to assist children with different learning challenges.

4. Game Development This chapter covers how the mini-games were developed. Design principles, methodologies and tools will be set each with its motives. Each mini-game's architecture will also be explored.

5. Experimental Evaluation Here the outcome of the project will be presented. This includes testing results, feedback gathered, and an analysis of how well the mini-games achieved their main goals.

6. Conclusions Finally, in the Conclusions we will look into an overall view of the problem and the developed solution. A summary of the obtained results and future work is discussed.

2 Related Work

The following chapter showcases related work relevant to this thesis project.

We'll start by clearly defining a learning disability (Section 2.1), which will help us design strategies to overcome these challenges. To better tailor the project to our intended users, we'll dive deep into research on each type of learning disability (Section 2.2).

After that, we will look into existing solutions on the market that can inform and enhance the development of this project (Section 2.3).

2.1 Learning Disabilities

A Learning Disability (LD) is a variation of neurological conditions that can affect the capacity of a person to process, understand and remember information or specific learning abilities, even when a person's intelligence is normal and learning opportunities are suitable.

These conditions can affect abilities such as reading, mathematics, reasoning, logic, visual and auditive comprehension, memory, and information organization. The common types of learning disabilities include dyslexia and dyscalculia [27].

The main causes of learning disabilities are not fully understood, but it's believed that genealogical, neurobiological, and environmental factors can be a root cause. It's important to highlight that learning disabilities aren't caused by lack of effort, motivation, or intelligence [44].

The diagnostic and treatment of learning disabilities can include a combination of educational interventions, behavioural therapies and medication, depending on the seriousness and the individual needs of each affected people. It is known that the practice of educational games can also overcome learning disabilities [27].

2.2 Overcoming Learning Disabilities

Children with learning disabilities face unique challenges both in their educational and social life. The use of interactive technology, specifically games, has shown great promise in helping these kids to deal with situations by providing an engaging learning experience specifically tailored for them. In this section, the state-of-the-art about the series of mini-games for supporting children with learning disabilities is addressed.

Game Based Learning GBL has emerged as an innovative approach to address the specific needs of children with LD's. This technique utilizes the power of games to define and support learning outcomes. This is a great way to help them learn due to the fact that games are already a big part in most of the children's playtime. The evolution of technology has provided lots of different ways people can play games and we often see children playing more in their laptop, tablet and even their smartphones. A GBL environment achieves these learning outcomes through educational games that have elements such as engagement, rewards, and healthy competition, making people stay motivated while learning [28].

Some important points should be addressed when designing a product like this. First of all, understanding the nature of LD's is crucial. LD's encompass a range of conditions that include Dyslexia, Dyscalculia, Language Processing Disorder (LPD), Non-Verbal Learning Disabilities, Dysgraphia, Auditory Processing Disorder, and Visual Motor Deficit.

In order to properly develop these mini-games we should have in mind the characteristics of these disabilities. This way, some research was done so that we can better understand each LD. For each one, we created a "User Profile" that contains the most likely Problems, Goals, Misconceptions, Needs, and Psychographics.

2.2.1 Dyslexia

Dyslexia is a common learning disability that affects reading and language processing skills. Children with dyslexia often struggle with various aspects of reading, including decoding, spelling, reading comprehension, and phonological memory. Understanding the user profile associated with dyslexia can guide the development of effective mini-games to address the specific goals, psychographics, problems, facts, and needs of children with this learning disability. Figure 2.1 depicts the Dyslexia user profile.

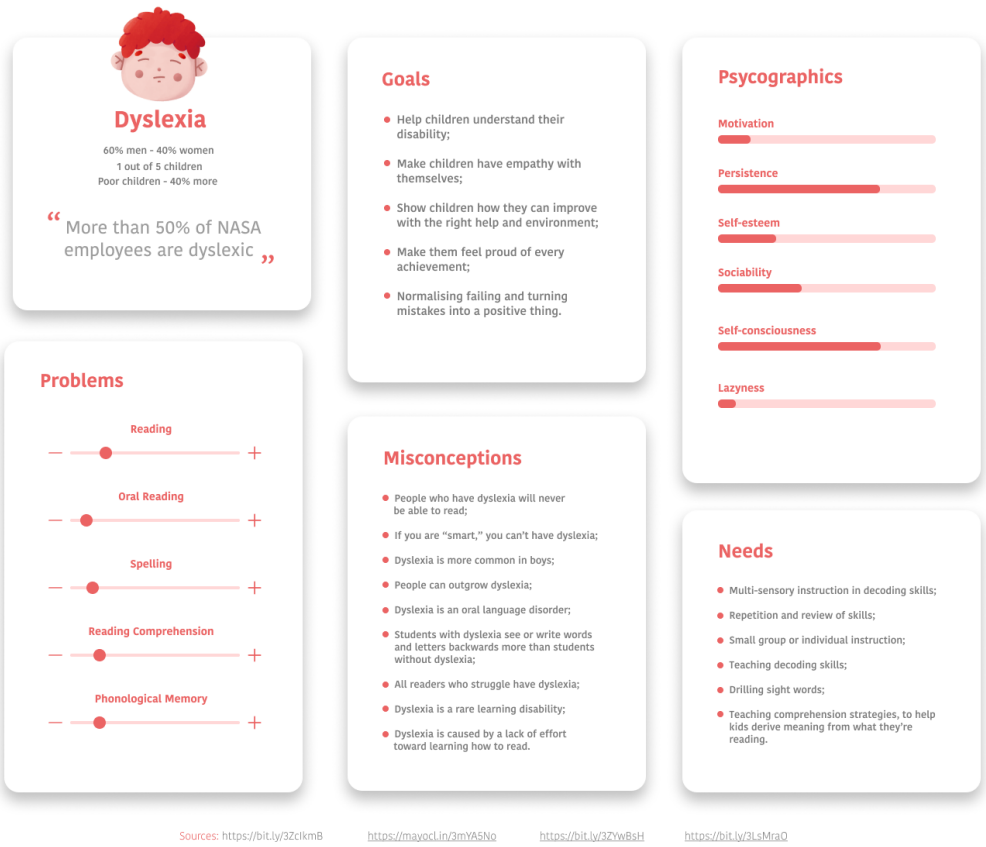

Figure 2.1: *Dyslexia User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a clear understanding of dyslexia, its effects on reading, and how it does not define their intelligence or potential.
- **Foster empathy and self-acceptance**: By creating an environment that encourages self-compassion and understanding, the mini-games aim to instill a sense of empathy within children towards themselves and others facing similar challenges.
- **Promote improvement through appropriate support**: The mini-games strive to demonstrate how with the right help and a supportive environment, children with dyslexia can make significant improvements in their reading abilities.

- **Cultivate a sense of achievement**: Recognizing and celebrating every milestone and achievement, no matter how small, is a key objective of the mini-games.
- **Normalize failure and embrace mistakes**: The mini-games aim to shift the perception of failure by illustrating that mistakes are an inherent part of the learning process and can lead to positive growth.

Psycographics

- **Low self-esteem**: Dyslexia can negatively impact self-esteem due to difficulties experienced in reading and academic settings [25].
- **Low laziness**: Despite the challenges they face, children with dyslexia typically demonstrate a strong work ethic and a drive to overcome difficulties [47].
- **Medium-low sociability**: Children with dyslexia may exhibit varying levels of sociability, often preferring smaller social groups or activities that do not heavily rely on reading [35].
- **High persistence**: Children with dyslexia often exhibit determination and persistence in overcoming challenges related to reading [47].
- **High self-consciousness**: Dyslexia can make children self-conscious about their reading abilities, leading to heightened self-awareness in educational settings.

Problems

- **Reading**: Difficulties in accurately and fluently recognizing and decoding words [4].
- **Reading Aloud**: Challenges in pronouncing words correctly and maintaining fluency while reading aloud [4].
- **Spelling**: Struggles with accurate spelling due to difficulties in connecting sounds to letters and understanding spelling patterns [4].
- **Reading Comprehension**: Difficulties in understanding and deriving meaning from written text, impacting overall comprehension skills [4].
- **Phonological Memory**: Challenges in remembering and manipulating speech sounds, affecting phonemic awareness and decoding skills [4].

Facts

- Dyslexia does not prevent individuals from learning how to read [4].
- Intelligence is not a determining factor in the presence of dyslexia [47].
- Dyslexia affects both boys and girls [4].
- Dyslexia is a lifelong learning disability, but individuals can make significant progress with appropriate interventions and support [4].

- Dyslexia primarily affects reading, not oral language skills [4].
- Reversing letters or words is not exclusive to dyslexia [4].
- Dyslexia is a relatively common learning disability.
- Dyslexia is not caused by a lack of effort or motivation to learn how to read.

Needs

- **Multi-sensory instruction in decoding skills**: Children with dyslexia benefit from instructional approaches that engage multiple senses simultaneously. This approach typically involves integrating visual, auditory, and kinesthetic modalities to reinforce letter-sound relationships and improve reading accuracy. For example, a mini-game could present letters or words visually while simultaneously providing auditory feedback or encouraging physical manipulation of letter tiles [25].
- **Repetition and review of skills**: Dyslexic learners require ample opportunities for practice and reinforcement of decoding skills. Repetition helps solidify their understanding of letter-sound associations, spelling patterns, and reading strategies. Mini-games can incorporate repeated exposure to target skills through varied and engaging activities, allowing children to reinforce their learning in an interactive and enjoyable manner [25].
- **Small group or individual instruction**: Dyslexia-specific instruction often benefits from personalized attention in small group settings or one-on-one instruction. Mini-games can be designed to accommodate different group sizes, allowing for targeted interventions and tailored support. Providing individualized feedback and adaptive features within the games can further enhance the effectiveness of small group or individual instruction [25].
- **Teaching decoding skills**: Dyslexic children often struggle with decoding, the process of translating written words into spoken language. Mini-games can focus on teaching and reinforcing decoding skills by incorporating activities that require the identification and blending of letter sounds, syllables, or whole words. Interactive feedback and scaffolding mechanisms can guide children through the decoding process, promoting accuracy and fluency [25].
- **Drilling sight words**: Sight words, also known as high-frequency words, are common words that dyslexic learners encounter frequently but do not follow regular phonetic patterns. Mini-games can include drills and practice exercises that specifically target sight words. By presenting these words repeatedly in engaging formats, such as word recognition games or word-building puzzles, dyslexic learners can improve their automatic recognition and reading fluency [25].
- **Teaching comprehension strategies to help derive meaning from text**: Reading comprehension is a significant challenge for individuals with dyslexia. Mini-games

can incorporate activities that teach and reinforce comprehension strategies, such as identifying main ideas, making inferences, summarizing information, and visualizing text. By practicing these strategies within interactive game contexts, children with dyslexia can develop stronger comprehension skills and derive meaning from what they read [25].

2.2.2 Language Processing Disorder

Language Processing Disorder (LPD) are neurodevelopmental conditions that hinder a child's ability to understand and use spoken language effectively. Individuals with LPD may face challenges with both understanding others and expressing themselves verbally, which can impact their social interactions, academic performance, and overall communication skills. Developing interventions tailored to children with LPD requires a deep understanding of their unique profiles. This means identifying their specific goals, psychographics, problems, characteristics, and needs related to language processing. Figure 2.2 depicts the LPD user profile.

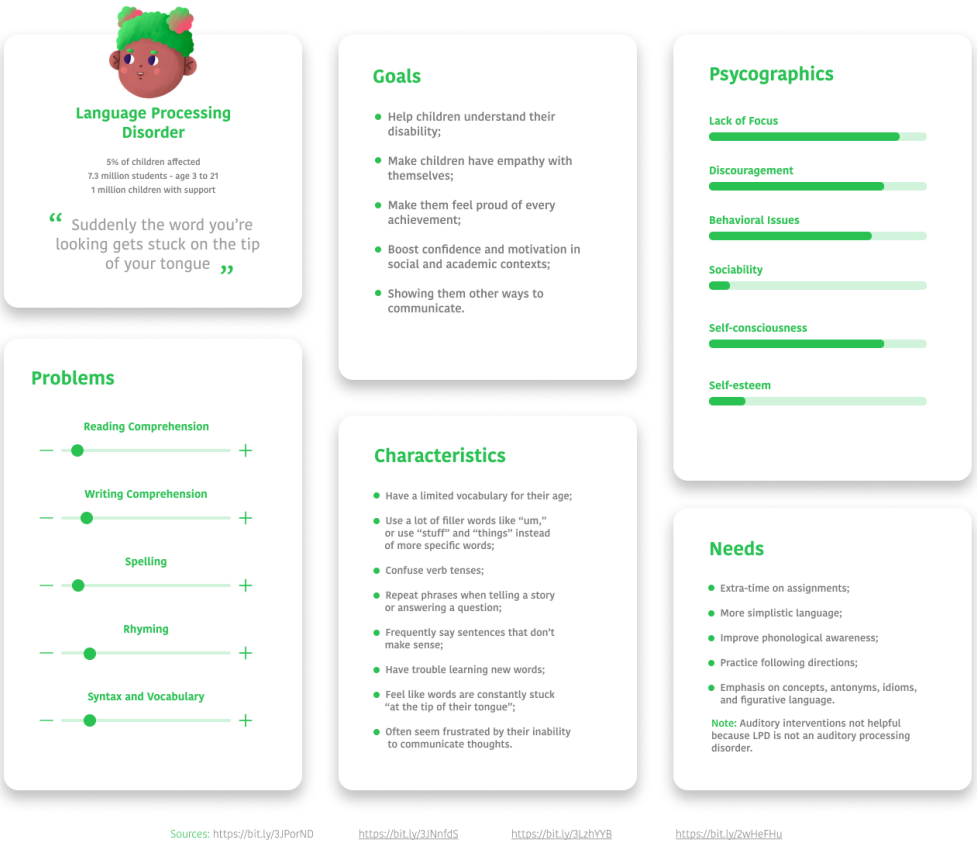

Figure 2.2: *Language Processing Disorder User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a clear understanding of Language Processing Disorder, its impact on their language skills, and how it does not define their intelligence or potential.

- **Foster empathy and self-acceptance**: By creating an environment that encourages self-compassion and understanding, the mini-games aim to instill a sense of empathy within children towards themselves and others facing similar challenges.
- **Foster pride in achievements**: Recognizing and celebrating every accomplishment, no matter how small, is a key objective of the mini-games.
- **Boost confidence and motivation in social and academic context**: The mini-games aim to enhance children's confidence and motivation to communicate effectively in social and academic settings.
- **Explore alternative communication methods**: The mini-games can introduce children to different ways of communication, such as visual aids, gestures, or assistive technologies, to overcome challenges related with language processing.

Psycographics

- **Low self-esteem**: Struggles with language processing can negatively impact children's self-esteem, making it important to design mini-games that foster a sense of accomplishment and build confidence [43].
- **Low sociability**: Due to communication challenges, children may show a preference for limited social interactions or struggle with initiating and maintaining conversations [33].
- **High lack of focus**: Children with LPD may struggle with keeping attention and concentration, making it important to design engaging and interactive mini-games [43].
- **High discouragement**: Difficulties in language processing can lead to frustration and discouragement in academic and social contexts.
- **High behavioral issues**: Children with Language Processing Disorder may exhibit behavioral challenges stemming from their communication difficulties [43].
- **High self-consciousness**: Language difficulties can make children self-conscious about their communication abilities, leading to heightened self-awareness in social and educational settings [24].

Problems

- **Reading and Writing Comprehension**: Difficulties in understanding and extracting meaning from written text and expressing thoughts in writing [43].
- **Spelling**: Challenges in accurately spelling words due to difficulties in phonemic awareness and sound-letter correspondence [43].
- **Rhyming**: Difficulty recognizing and generating rhyming words, impacting phonological awareness [43].

- **Syntax and Vocabulary**: Challenges with understanding and using grammatical rules and acquiring and retaining a wide range of vocabulary [24].

Characteristics

- **Limited vocabulary for their age**: They may have a smaller repertoire of words compared to their peers [24].
- **Use of filler words and vague language**: They may rely on filler words like ”hum” or use general terms like ”stuff” and ”things” instead of specific words [24].
- **Confusion with verb tenses**: Difficulties in using and understanding appropriate verb tenses [33].
- **Repetition of phrases**: They may repeat phrases when telling stories or answering questions [24].
- **Incoherent sentences**: Frequent production of sentences that do not make sense or lack cohesion [24].
- **Trouble learning new words**: Challenges in acquiring and retaining new vocabulary [24].
- **Tip-of-the-tongue phenomenon**: Feelings of frustration when they cannot retrieve specific words or express their thoughts [24].

Needs

- **Extra time on assignments**: Providing additional time for completing tasks and assignments to accommodate the slower processing speed [43].
- **Simplified language**: Using clear and concise language that is appropriate for the children's understanding level and to avoid complex sentence structures [24].
- **Improving phonological awareness**: Incorporating activities in the mini-games that focus on recognizing and manipulating sounds within words, such as rhyming, segmenting, and blending [43].
- **Practice following directions**: Designing mini-games that involve following sequential instructions to improve understanding and processing of spoken language [43].
- **Emphasis on concepts, antonyms, idioms, and figurative language**: Including activities that target understanding and using abstract language concepts, such as opposites, idiomatic expressions, and figurative language, to expand their language skills [43].

2.2.3 Dyscalculia

Dyscalculia is a learning disorder that primarily affects a child's ability to understand and work with numbers. Individuals with dyscalculia often encounter challenges in basic arithmetic operations, number sense, and mathematical reasoning. To develop effective interventions for children with dyscalculia, it is crucial to understand their unique user profile. This includes identifying their specific goals, psychographics, problems, characteristics and needs related to mathematical learning. Figure 2.3 depicts the Dyscalculia user profile.

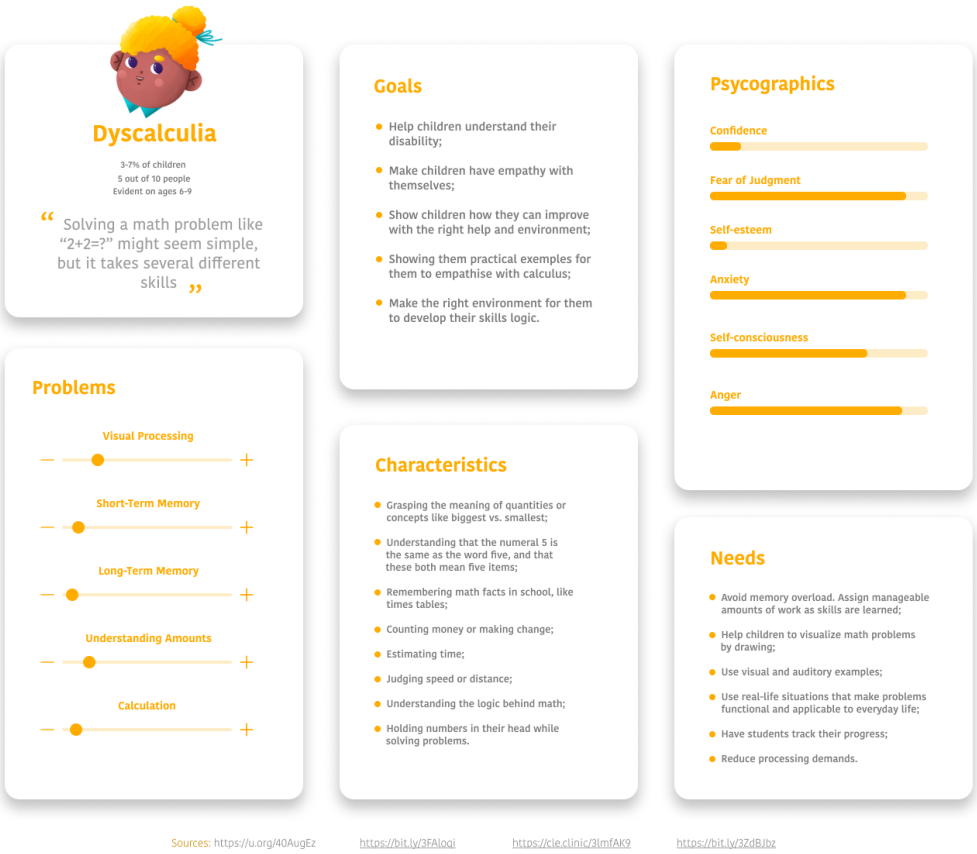

Figure 2.3: *Dyscalculia User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a clear understanding of Dyscalculia, its impact on their mathematical abilities, and how it does not define their overall intelligence.
- **Foster empathy and self-acceptance**: By creating an environment of empathy and self-acceptance, the mini-games aim to help children develop a positive self-image and reduce negative emotions related to their difficulties with mathematics.
- **Show children how they can improve**: The mini-games should demonstrate to children that with the right help, strategies, and environment, they can improve their mathematical skills and overcome challenges associated with Dyscalculia.

- **Provide practical examples for empathy with calculus**: The mini-games can present practical examples or real-life scenarios to help children develop an empathetic understanding of mathematical concepts and their relevance in everyday life.
- **Create an environment for logical skill development**: The mini-games should provide a supportive and stimulating environment for children to develop their logical and mathematical reasoning abilities.

Psycographics

- **Low confidence**: Children with Dyscalculia often struggle with their mathematical abilities, leading to low confidence in their own skills [36].
- **Low self-esteem**: Struggles with mathematics can negatively impact self-esteem and self-worth [7].
- **High fear of judgment**: Due to difficulties with math, children may fear being judged or evaluated negatively by peers or teachers [36].
- **High anxiety**: Children with Dyscalculia may experience anxiety or stress when faced with mathematical tasks or assessments [30].
- **High self-consciousness**: Difficulties with mathematics can make children self-conscious about their abilities and performance in academic settings [36].
- **High anger**: Frustration arising from mathematical challenges can lead to feelings of anger or irritability [7].

Problems

- **Visual processing**: Difficulties in processing and interpreting visual information related to numbers, symbols, and mathematical representations [36].
- **Short/Long-Term memory**: Challenges in retaining and recalling mathematical facts, formulas, and procedures from both immediate and long-term memory [7].
- **Understanding amounts**: Difficulty grasping the concept of quantity, comparing magnitudes, and understanding number relationships [7].
- **Calculation**: Challenges in performing mathematical calculations, such as addition, subtraction, multiplication, and division [36].

Characteristics

- **Grasping the meaning of quantities or concepts**: Difficulties in understanding concepts such as big versus small, more versus less, or numerical symbols representing quantities [7].

- **Understanding number-word correspondence**: Struggles in connecting numeral symbols with their corresponding written words and comprehending that they both represent the same quantity [36].
- **Remembering math facts**: Challenges in recalling and memorizing math facts, such as timestables or basic arithmetic operations [7].
- **Counting money or making change**: Difficulties in accurately counting money, making change, or understanding monetary concepts [7].
- **Estimating time**: Trouble estimating and judging the passage of time accurately [36].
- **Judging speed or distance**: Challenges in assessing speed, distance, or spatial relationships [30].
- **Understanding the logic behind math**: Difficulties in comprehending the underlying logic and reasoning behind mathematical concepts and operations [36].
- **Holding numbers in their head**: Struggles in retaining and manipulating numbers mentally while solving mathematical problems [7].

Needs

- **Avoiding memory overload**: Assigning manageable amounts of work that align with children's learning abilities and gradually increasing the complexity as skills are learned and mastered [7].
- **Visualizing math problems**: Incorporating visual elements and encouraging children to draw or visualize mathematical problems to enhance understanding and problem-solving [36].
- **Utilizing visual and auditory examples**: Presenting mathematical concepts and problems through visual and auditory means to address different learning modalities and enhance comprehension [30].
- **Real-life applications**: Designing mini-games that incorporate real-life situations and practical examples to demonstrate the functional and applicable aspects of mathematical concepts in everyday life [36].
- **Tracking progress**: Providing mechanisms for children to track their progress and achievements within the mini-games to foster a sense of accomplishment and motivation.
- **Reducing processing demands**: Implementing strategies and adjustments within the mini-games to reduce cognitive processing demands, such as providing additional time, scaffolding instructions, or offering alternative problem-solving approaches [36].

2.2.4 Non-Verbal Learning Disabilities (NVLD)

Non-verbal learning disabilities (NVLD) are neurodevelopmental conditions that impact a child's ability to understand and interpret non-verbal cues and information. Individuals with NVLD may struggle with social interactions, visual-spatial skills, motor coordination, and executive functioning. To develop interventions tailored to the needs of children with NVLD, it is essential to comprehend their unique user profile. This includes identifying their specific goals, psychographics, problems, characteristics and needs related to non-verbal learning. Figure 2.4 represents the NVLD user profile.

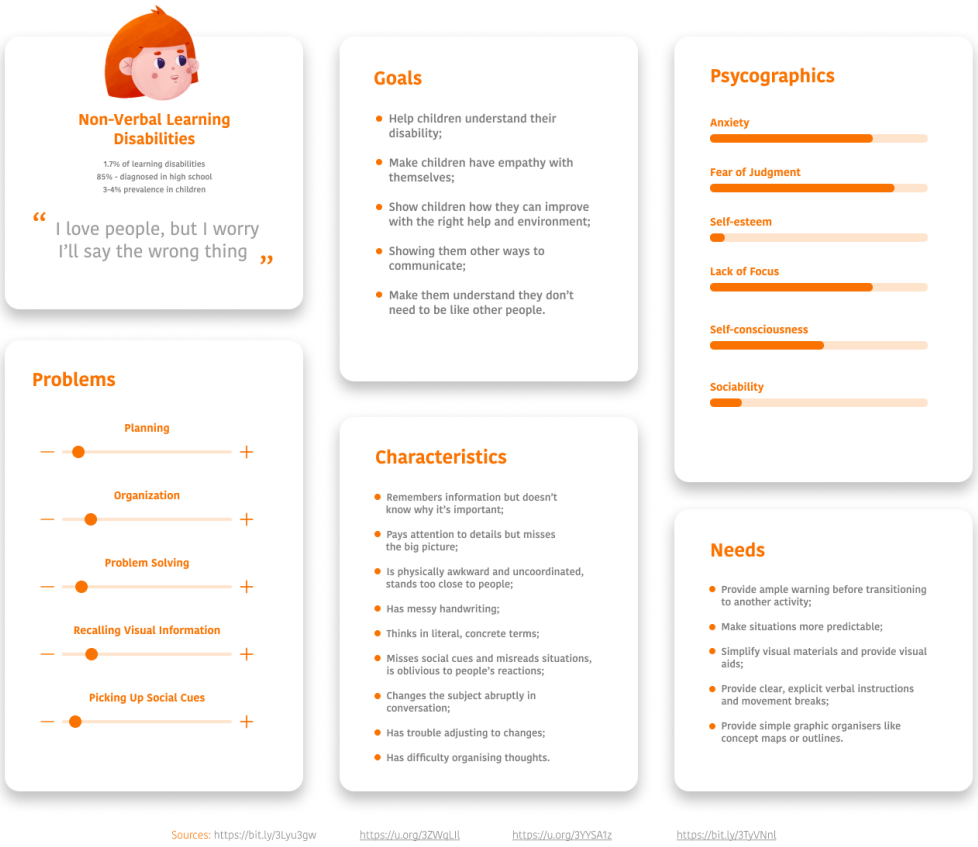

Figure 2.4: *Non-Verbal Learning Disabilities User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a comprehensive understanding of NVLD, its impact on their cognitive and social abilities, and how it shapes their unique strengths and challenges.
- **Foster empathy and self-acceptance**: By creating an environment of empathy and self-acceptance, the mini-games aim to help children develop a positive self-image, embrace their differences, and build resilience in the face of challenges.
- **Show children how they can improve**: The mini-games should convey to children that with the right help, strategies, and supportive environment, they can improve

their cognitive and social skills and navigate their daily lives more effectively.

- **Explore alternative communication methods**: The mini-games can introduce and explore different modes of communication to help children with NVLD find alternative ways to express themselves effectively.
- **Promote self-acceptance**: The mini-games aim to instill in children the understanding that they do not need to conform to societal expectations and that their unique strengths and perspectives are valuable.

Psycographics

- **Low self-esteem**: Struggles with cognitive and social skills can lead to lower self-esteem and self-worth [17].
- **Average self-consciousness**: Children may have an average level of self-consciousness, as they are aware of their challenges but may not fully comprehend the underlying reasons [17].
- **High anxiety**: Children with NVLD often experience heightened levels of anxiety related to their difficulties in processing and understanding social and nonverbal cues [17].
- **High fear of judgment**: Due to challenges in social interactions, children may have a heightened fear of being judged or evaluated negatively by others [17].
- **High lack of focus**: Difficulties in sustaining attention and focusing on relevant information may be characteristic of children with NVLD [37].
- **Low sociability**: Difficulties in social interactions may result in lower levels of social engagement and interaction [37].

Problems

- **Planning**: Difficulties in organizing and executing sequential tasks or activities effectively [17].
- **Organization**: Challenges in managing and structuring information, materials, and personal belongings [17].
- **Problem-solving**: Difficulties in identifying problems, generating solutions, and implementing strategies to solve them effectively [19].
- **Recalling visual information**: Challenges in remembering and recalling visual information, such as faces, or visual details [37].
- **Picking up social cues**: Difficulty in understanding and interpreting nonverbal cues, gestures, facial expressions, and body language [2].

Characteristics

- **Remembering information without understanding its significance**: The ability to recall information but struggling to grasp its importance or connect it to broader contexts [37].
- **Attention to details at the expense of the big picture**: Focusing on specific details while overlooking the overall context or main idea [37].
- **Physical awkwardness and coordination difficulties**: Exhibiting motor coordination challenges, such as standing too close to others, clumsiness, or poor spatial awareness [37].
- **Messy handwriting**: Difficulty in producing legible and organized written work [37].
- **Literal, concrete thinking**: Tendency to think and interpret information in a literal and concrete manner, struggling with abstract or ambiguous concepts [37].
- **Missing social cues and misreading situations**: Difficulty in understanding and responding to social cues, resulting in misinterpretation of social situations and unawareness of others' reactions [37].
- **Abruptly changing the subject in conversation**: Shifting topics abruptly during conversations without recognizing the need for smooth transitions [37].
- **Difficulty adjusting to changes and transitions**: Resistance to changes in routines or environments, finding it challenging to adapt and adjust to new situations [37].
- **Difficulty organizing thoughts**: Struggles in structuring and organizing thoughts coherently, leading to difficulties in expressing ideas and communicating effectively [37].

Needs

- **Providing ample warning before transitioning**: Offering clear and advanced notice when transitioning from one activity or task to another, allowing children to mentally prepare and adjust [20].
- **Making situations more predictable**: Creating predictable and structured environments to reduce anxiety and provide a sense of stability and security [20].
- **Simplifying visual materials and providing visual aids**: Presenting visual materials in a simplified manner, using visual aids, diagrams, or illustrations to enhance understanding and facilitate information processing [20].
- **Providing clear, explicit verbal instructions**: Offering precise and unambiguous verbal instructions to ensure clarity and comprehension, helping children to navigate through tasks and activities more effectively [20].

- **Incorporating movement breaks**: Introducing regular movement breaks within the mini-games to allow children to release energy, improve focus, and enhance cognitive functioning [20].
- **Providing simple graphic organizers**: Offering graphic organizers such as concept maps or outlines to assist children in organizing their thoughts, fostering structured thinking and facilitating effective communication [20].

2.2.5 Dysgraphia

Dysgraphia is a learning disability that primarily impacts a child's ability to write coherently and express their thoughts through written language. Individuals with dysgraphia may struggle with handwriting, spelling, grammar, and organizing their ideas on paper. In order to develop effective interventions for children with dysgraphia, it is important to understand their unique user profile. This includes identifying their specific goals, psychographics, problems, characteristics, and needs related to written expression and communication. Figure 2.5 displays the Dysgraphia user profile.

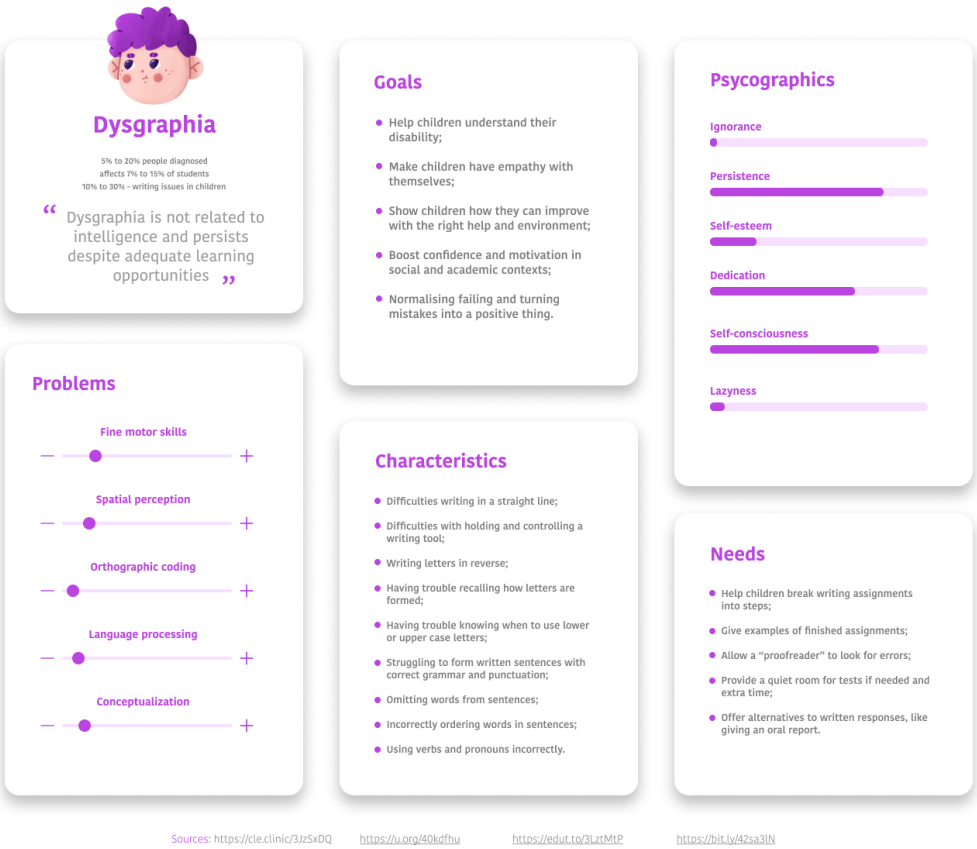

Figure 2.5: *Dysgraphia User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a comprehensive understanding of Dysgraphia, its impact on their

writing skills, and the specific challenges they may face.

- **Foster empathy and self-acceptance**: By creating an environment of empathy and self-acceptance, the mini-games aim to help children develop a positive self-image, embrace their unique writing style, and build resilience in the face of writing difficulties.
- **Show children how they can improve**: The mini-games should demonstrate to children that with the right help, strategies, and supportive environment, they can improve their writing skills and overcome specific challenges related to Dysgraphia.
- **Boost confidence and motivation**: The mini-games aim to boost children's confidence in their writing abilities, celebrate their progress and achievements, and enhance their motivation to engage in writing tasks both in social and academic contexts.
- **Normalize failing and turning mistakes into a positive thing**: Creating a positive learning environment within the mini-games that encourages children to view mistakes as opportunities for growth and learning, fostering a growth mindset and resilience.

Psychographics

- **Low laziness**: Exhibiting a proactive and engaged attitude towards writing tasks.
- **Low ignorance**: Children with Dysgraphia generally have awareness of their writing difficulties and the challenges they face [6].
- **Low self-esteem**: Struggling with writing can negatively impact self-esteem and self-worth [6].
- **High persistence**: Demonstrating persistence and determination in overcoming writing challenges despite all the setbacks.
- **High dedication**: Displaying a strong commitment and effort in improving writing skills.
- **High self-consciousness**: Being self-conscious about their writing abilities in comparison to their peers.

Problems

- **Fine motor skills**: Difficulties in controlling and coordinating fine motor movements required for writing [6].
- **Spatial perception**: Challenges in perceiving and reproducing correct spacing, alignment, and proportions of letters and words on a page [6].
- **Orthographic coding**: Struggles in remembering and accurately reproducing the correct formation and shape of letters and words [6].

- **Language processing**: Difficulties in organizing and expressing thoughts in written form, including grammar, sentence structure, and punctuation [6].
- **Conceptualization**: Challenges in generating and organizing ideas coherently and effectively [6].

Characteristics

- **Difficulties writing on a straight line**: Struggling to maintain a consistent baseline or alignment while writing [6].
- **Difficulties with holding and controlling a writing tool**: Challenges in gripping and controlling the pen or pencil while writing [41].
- **Writing letters in reverse**: Frequently reversing or inverting letters or numbers [1].
- **Trouble recalling letter formation**: Difficulty on remembering and reproducing the proper formation of letters [8].
- **Difficulty with capitalization**: Confusion regarding when to use uppercase or lowercase letters [6].
- **Struggling with grammar and punctuation**: Difficulties in using correct grammar, punctuation, and sentence structure [6].
- **Omitting or misordering words**: Frequently leaving out words or rearranging them incorrectly within sentences [6].
- **Incorrect verb and pronoun usage**: Using verbs and pronouns incorrectly, leading to grammatical errors [6].

Needs

- **Breaking writing assignments into steps**: Providing clear and structured instructions, breaking down writing tasks into manageable steps to enhance organization and reduce overwhelm [41].
- **Providing examples of finished assignments**: Offering visual models and examples of well-organized and properly completed assignments helps to understand expectations [41].
- **Allowing a "proofreader" to look for errors**: Incorporating a feature within the mini-games that allows children to have their written work reviewed by a virtual or real person to identify and correct errors, providing feedback and guidance [41].
- **Providing a quiet room for tests if needed and extra time**: Recognizing the potential impact of environmental distractions on writing performance and offering a quiet and focused space for assessments, along with appropriate time extensions to accommodate the specific needs of children with Dysgraphia [41].

- **Offering alternatives to written responses**: Recognizing that writing may pose significant challenges for children with Dysgraphia, the mini-games should provide opportunities for alternative modes of expression, such as giving oral reports or utilizing multimedia formats [41].

2.2.6 Auditory Processing Disorder

Auditory Processing Disorder (APD) is a neurological condition that affects a child's ability to accurately process and interpret auditory information. Individuals with APD may have difficulty distinguishing sounds, recognizing speech patterns, understanding spoken language, and filtering out background noise. To develop interventions tailored to the needs of children with an auditory processing disorder, it is important to understand their unique user profile. This includes identifying their specific goals, psychographics, problems, characteristics and needs related to auditory processing and communication. Figure 2.6 represents the APD user profile.

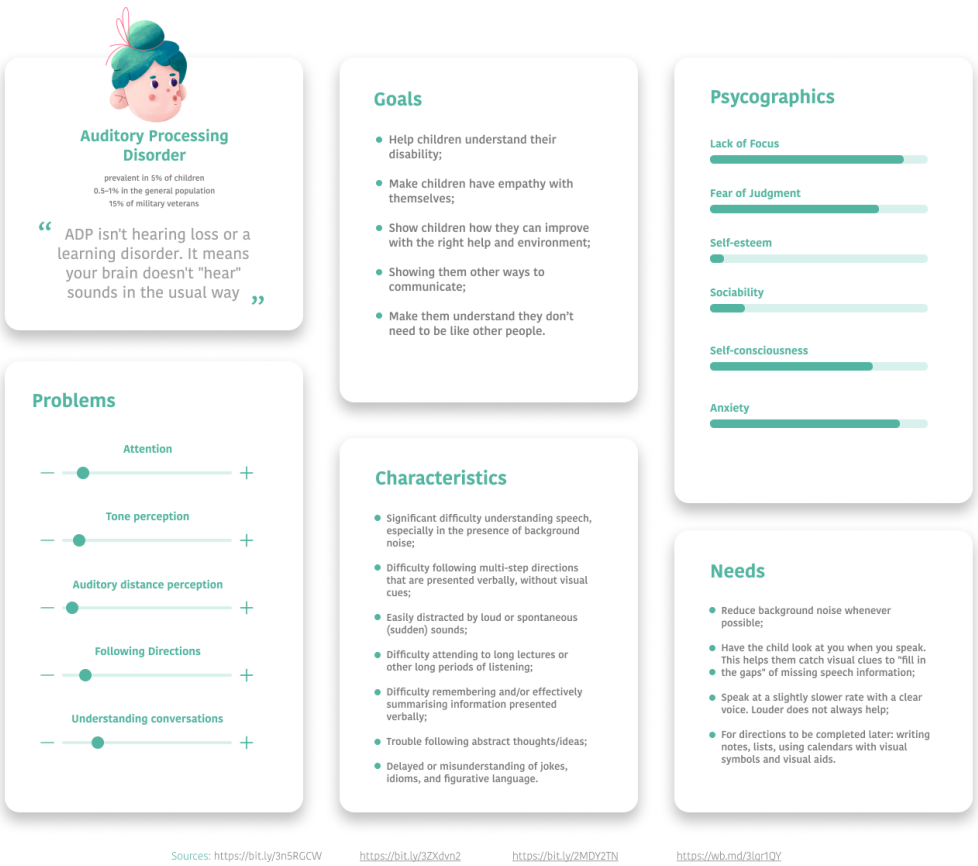

Figure 2.6: *Auditory Processing Disorder User Profile*

Goals

- **Help children understand their disability**: The mini-games aim to provide children with a comprehensive understanding of APD, including its impact on their auditory processing skills and the specific challenges they may face in communication and comprehension.

- **Foster empathy and self-acceptance**: By creating an environment of empathy and self-acceptance, the mini-games aim to help children develop a positive self-image, embrace their unique auditory processing abilities, and build resilience in the face of auditory challenges.
- **Show children how they can improve**: The mini-games should demonstrate to children that with the right help, strategies, and supportive environment, they can improve their auditory processing skills and effectively navigate through various listening situations.
- **Provide alternative communication methods**: The mini-games aim to explore and provide children with alternative ways to communicate and comprehend information beyond traditional auditory channels.
- **Promote self-acceptance**: The mini-games should emphasize that children with APD do not need to compare themselves against others and that their unique auditory processing abilities are valuable in their own right.

Psychographics

- **Low self-esteem**: Struggles with self-worth and confidence, often influenced by difficulties in understanding and responding appropriately to spoken language [21].
- **Low sociability**: Tendency to withdraw from social interactions due to challenges in understanding and participating in conversations [21].
- **High lack of focus**: Difficulty maintaining attention and concentration in auditory tasks due to the challenges in processing auditory information accurately [26].
- **High fear of judgment**: Anxiety and fear of being misunderstood or judged by others due to difficulties in comprehending verbal instructions or conversations [21].
- **High self-consciousness**: Heightened awareness of their auditory difficulties and how they may be perceived by others [21].
- **High anxiety**: Experiencing elevated levels of anxiety, particularly in situations involving complex auditory input or noisy environments [21].

Problems

- **Attention**: Difficulties in sustaining attention and focus on auditory tasks, particularly in the presence of background noise or competing stimuli [16].
- **Tone perception**: Challenges in accurately perceiving and interpreting subtle variations in tone and intonation in spoken language, affecting the ability to understand emotions, sarcasm, or subtle nuances in communication [26].
- **Auditory distance perception**: Difficulties in accurately perceiving the distance or location from which sounds originate, which can lead to challenges in localizing sounds or distinguishing relevant auditory cues [21].

- **Following directions**: Difficulty comprehending and remembering multi-step directions or instructions that are presented verbally, without visual cues [26].
- **Understanding conversations**: Struggles in processing and comprehending conversations, especially in situations with multiple speakers, fast-paced speech, or complex language structures [26].

Characteristics

- **Significant difficulty understanding speech, especially in the presence of background noise**: Struggling to extract relevant information from auditory stimuli, leading to challenges in understanding speech in noisy environments [26].
- **Difficulty following multi-step directions without visual cues**: Finding it challenging to retain and follow verbal instructions that involve multiple steps or complex sequencing [45].
- **Easily distracted by loud or spontaneous sounds**: Exhibiting heightened sensitivity to environmental sounds and being easily overwhelmed by unexpected or sudden auditory stimuli [26].
- **Difficulty attending to long lectures or extended periods of listening**: Struggling to sustain attention and focus during lengthy auditory tasks, such as lectures or extended conversations [26].
- **Difficulty remembering and summarizing information presented verbally**: Challenges in retaining and accurately summarizing information presented in spoken form, impacting learning and information processing [26].
- **Trouble following abstract thoughts and ideas**: Finding it challenging to grasp abstract concepts or complex ideas conveyed through spoken language [26].
- **Delayed or misunderstanding of jokes, idioms, and figurative language**: Difficulties in comprehending and interpreting humor, idiomatic expressions, metaphors, and figurative language, which rely heavily on auditory processing skills [26].

Needs

- **Reduce background noise whenever possible**: Creating an auditory environment with minimal distractions and background noise to optimize the child's ability to focus on and process auditory information [26].
- **Encourage visual cues**: Promoting the use of visual cues, such as maintaining eye contact, gestures, facial expressions, and visual aids, to supplement auditory input and enhance comprehension [26].
- **Modify speech delivery**: Speaking at a slightly slower rate with a clear and distinct voice, ensuring that instructions and information are presented in a manner that

facilitates comprehension for children with APD. Louder speech may not necessarily help and can potentially increase sensory overload [21].

- **Provide visual supports**: Utilizing visual supports, such as written notes, lists, calendars with visual symbols, and visual aids, to reinforce verbal information and assist with memory recall and organization [21].
- **Offer alternative communication methods**: Incorporating alternative modes of communication, such as visual or written responses, within the mini-games to accommodate the needs and preferences of children with APD [21].
- **Individualize learning experiences**: Designing mini-games such that they can adapt to the unique learning profile of each child with APD, providing personalized challenges and support to foster growth and skill development [21].

2.2.7 Visual Motor Deficit

Visual motor deficit, also known as visual-motor integration difficulty, refers to a condition that impacts a child's ability to coordinate visual perception with motor skills. Individuals with visual motor deficits may experience challenges in tasks requiring hand-eye coordination, spatial awareness, and fine motor control. To develop interventions tailored to the needs of children with visual motor deficits, it is important to understand their unique user profile. This includes identifying their specific goals, psychographics, problems, characteristics, and needs related to visual-motor integration and motor coordination. Figure 2.7 depicts the Visual Motor Deficit user profile.

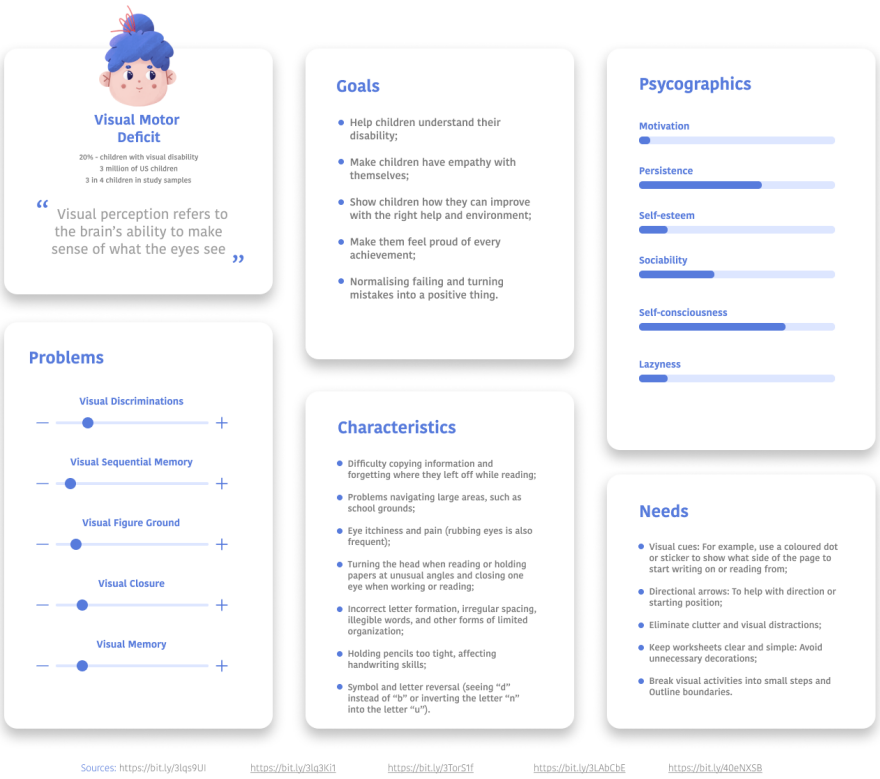

Figure 2.7: *Visual Motor Deficit User Profile*

Goals

- Helping children understand their disability and fostering self-empathy.
- Demonstrating how improvement is achievable with appropriate support and an enabling environment.
- Cultivating a sense of pride in every achievement, no matter how small it is.
- Promoting a positive mindset towards failure, grooming mistakes into opportunities for growth.

Psycographics

- Low motivation and self-esteem due to persistent challenges.
- High levels of persistence, showing determination to overcome difficulties.
- Average sociability, seeking opportunities for interaction with peers.
- Heightened self-consciousness about their motor skills.
- Low levels of laziness, indicating a willingness to invest effort in learning and development.

Problems

- **Visual discriminations**: Difficulty distinguishing and recognizing visual details accurately [34].
- **Visual sequential memory**: Struggles in remembering and reproducing visual sequences in the correct order [34].
- **Visual figure-ground**: Difficulty differentiating foreground from background in visual stimuli [34].
- **Visual closure**: Challenges in perceiving complete images or letters when parts are missing [34].
- **Visual memory**: Difficulty retaining and recalling visual information accurately [34].

Characteristics

- Difficulty copying information accurately and maintaining their place while reading [34].
- Challenges in navigating large areas and perceiving spatial relationships [34].
- Frequent eye itchiness and pain, leading to rubbing of the eyes [34].

- Unusual head movements or holding papers at atypical angles while reading or working [34].
- Poor letter formation, irregular spacing, and illegible handwriting [34].
- Excessive grip pressure on pencils, impacting handwriting skills [34].
- Reversal of symbols and letters, such as mistaking ”d” for ”b” or inverting the letter ”n” into ”u” [34].

Needs

- **Visual cues**: Incorporating visual aids, such as colored dots or stickers, to signal the starting point for writing or reading [5].
- **Directional arrows**: Providing clear visual cues to assist with direction and starting positions [5].
- **Minimizing clutter and distractions**: Creating organized and uncluttered learning environments to enhance focus and concentration [5].
- **Simplifying worksheets**: Presenting worksheets with clear, straightforward designs and avoiding unnecessary decorations [5].
- **Breaking activities into small steps**: Breaking down visual tasks into manageable steps to facilitate understanding and completion [5].
- **Outlining boundaries**: Using visual cues, such as borders or highlighting, to delineate boundaries within worksheets or assignments [5].

2.3 Some examples

Before the development of the games themselves, we should first look into some other existing solutions. This will allow for some advantages as we can analyse each one, knowing which characteristics are better suited for the mini-games being developed in this thesis. As we are developing different games targeted for different age groups and disabilities, we will have to group our research for games that aim to help for each LD. This way, we can capture some characteristics for each game and it will be easier when developing each mini-game from scratch. Next, we'll present some of the games found that can be useful for the research.

Fast ForWord

Fast ForWord[32] is a game that helps children will **dyslexia** and **Language Processing Disorder** to improve their phonological awareness, auditory processing and skills. It uses adaptive technology to provide individualized feedback and instruction. Fast ForWord is based on the neuroscience principles of neuroplasticity, the ability of the brain to change and adapt in response to stimulation and learning. It consists of two phases: cognitive and reading. The cognitive phase works on skill gaps and building fundamentals, such as processing, working memory, attention, and sequencing. The reading phase trains reading fluency and comprehension as well as vocabulary, grammar, and syntax. It has 9 programs in total each with 5-7 exercises that target different aspects of learning and reading. Each program is designed for different age groups and levels of difficulty. According to a meta-analysis of over 300 efficacy and research studies, Fast ForWord users achieved an average gain of 2 years in reading skills in about 6 months. [22] One of the games consists of listening to a story and then answering questions and following instructions. This improves skills in listening comprehension and builds familiarity with English language conventions. Figure 2.8 shows the aspect of this game in specific.

Figure 2.8: *Fast ForWord - Cosmic Reader*

NumberShire

NumberShire [29] is an internet-based game that aims at educationg children with intense focus on critical whole number concepts and skills for students. It is made for all students, but specially for those with difficulties in mathematics. This directly impacts children with dyscalculia and other math-related LDs.

It was developed with support from the U.S Department of Education. It achieved great results in several controlled trials, with students having significant gains in their math skills,

against students with typical math support.

The game is composed of mathematical concepts in a story-based, fantasy setting. Players complete quests by solving math problems tailored to their specific skill level. Through this narrative, children learn foundational math concepts such as addition, subtraction, and number sense. The game provides immediate feedback and rewards progress, creating a motivational framework that encourages practice.

Figure 2.9 details the visual representation of the gameplay.

Figure 2.9: *NumberShire - Gameplay*

GraphoGame

GraphoGame [12] is an educational game developed by a Finnish company. The game is meant to be played on touch-screen devices such as smartphones or tablets.

In the game, players create their own avatar and start to train from the most fundamental skills. It starts with letter recognizing, connecting letters with sounds. After that, children start to do letter combinations, combining sounds into syllabes and, lastly they move to challenging syllabes and complicated words. This sequence is know as the synthetic approach to reading instruction.

The game adapts in real-time to the child's performance, offering more challenging or simplified content based on their success rate. This adaptive nature is particularly beneficial for children with dyslexia, as it allows for targeted practice on challenging areas without overwhelming the learner. It utilizes a simple interface, having all instructions spoken aloud. GraphoGame is designed for children aged from six to eight years old. However it can be useful for readers of any age [31].

Figure 2.10 displays one of the challenges inside the game.

Figure 2.10: *GraphoGame - Gameplay*

3 Game Design and Mechanics

In this chapter, we take a detailed look at the mini-games developed. There will be an explanation of how each game is played and the specific skills each one aims to improve.

After describing each one, we'll display some screenshots. This way, we'll showcase a clear understanding of how the games work and the objectives they're designed to achieve.

Section 3.1 will focus on the Hearts Game, a simple fun game for to catch hearts on the screen.
Section 3.2 takes a look at the Maze Game, that has players move around a maze to find its exit.
Section 3.3 represents the Sounds Game, where players have to pay attention to the sounds matching them with real objects on screen.
Section 3.4 does a deep dive into the Words Game, that has children with their vocabulary.
Section 3.5 details the gameplay of the Puzzle game, where children are challenged with ecological puzzles of many difficulties.

3.1 Game 1 - Hearts

The Hearts Game is the first one and simplest game. This is because it is targeted for children between the age of 6 to 10 years old.

Description

The game consists of multiple hearts showing up on screen, which the child must click in order to score points. When some heart isn't pressed within some time limit, it gets destroyed and decreases the score points.

The game progresses along three different levels. These levels introduce the increase of the speed the hearts spawn and also new distracting hearts that also get spawned but shouldn't be clicked, damaging the score.

Success would be when the user is able to hit most of the hearts, while failure occurs when the child hits too many distractor hearts or is unable to hit most of the hearts present on the screen.

With this in mind, the player will have to adopt the following user actions:

- **Identify and Click** the hearts on the screen.
- **Avoid any distractors** that may appear.
- **Adapt to the speed** of spawning of hearts.

Competences

Despite being simple, the game allows for multiple competence acquisition from the children such as:

- **The Visual Attention and Processing Speed**- Children must identify and hit the hearts really quickly, enhancing their ability to focus and respond promptly. This is a crucial skill for children with **Visual Motor Deficit** and **Non-Verbal Learning Disabilities**.
- **Hand-Eye Coordination and Fine Motor Skills**- Each click in a heart requires precise hand-eye coordination, which helps to improve fine motor skills, greatly beneficial for children with **Dysgraphia** and **Visual Motor Deficit**.
- **Impulsivity Control and Decision Making**- As the difficulty increases, there are some hearts which should not be clicked. This challenges the child to control impulsive actions and take careful decisions. This is really beneficial for children with or **Non-Verbal Learning Disabilities**.

Figures 3.1 and 3.2, display the game during gameplay.

Figure 3.1: *Hearts Game - Home*

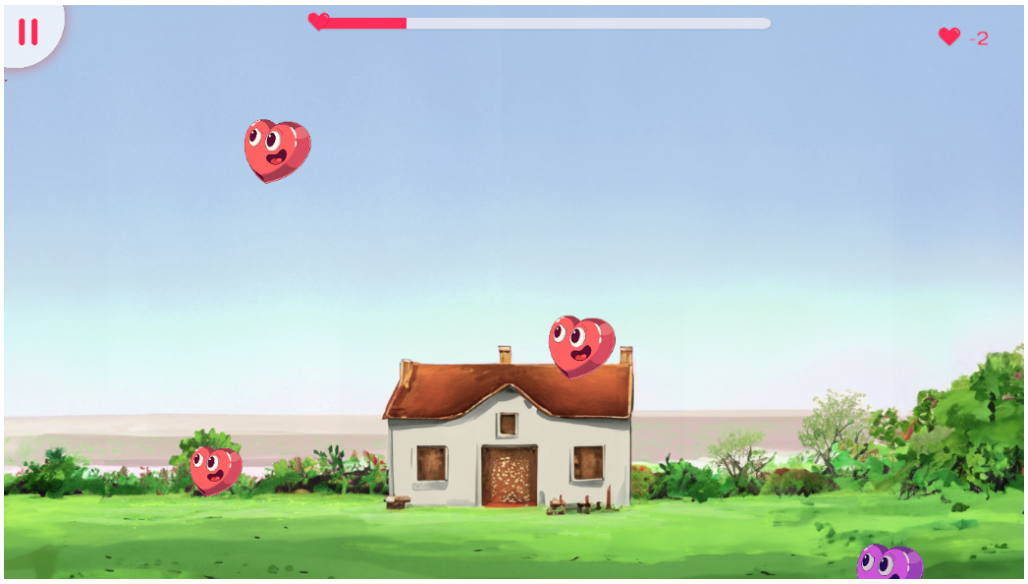

Figure 3.2: *Hearts Game - Gameplay*

3.2 Game 2 - Maze

The Maze Game is designed for children between the age of 6 to 12 years old.

Description

This game consists of a maze where the main character, Mr. Pig, has to navigate through a forest in order to find the exit. One of Mr. Pig's challenges is to pick up all gargabe he finds along the way, to keep nature clean.

During the game play the user's primary action is to navigate Mr. Pig through the maze using, either the arrow keys or drag and drop gestures. Before completing the maze, it's expected that the player finds all the objects that are not healthy for nature. At the end

of the maze, the player is met with a recycling bin for all the garbage collected.

By collecting each object in the forest, the user is met with positive reinforcement like sounds and notifications encouraging to move forward and progress to other levels. If the player fails to collect all objects in the forest before reaching the end, some feedback will show on screen to encourage the completion of the level.

This game's metric for success is the elapsed time and allows the players to complete each level at any pace, but with a highscore system keeps them motivated to beat the highest score and be faster.

Competences

The following are some of the competences this game aims to improve

- **Problem Solving**- Children must plan their route through the maze, getting to the most efficient path to collect all objects and reach the exit, which helps improve critical thinking and decision making. This can help a lot children with **Dyslexia** and **Dyscalculia**.
- **Visual-Motor Integration**- It helps to improve the coordination between visual perception and motor control. Navigating the player through the maze requires the processing of visual information about the maze's layout and respond with precise movements. This is really beneficial for children with **Visual Motor Deficit**.
- **Language Processing and Comprehension**- Because the game incorporates simple instructions that require the child to follow directions, it improves language comprehension, which is really helpful for children with **Language Processing Disorder**.

Figures 3.3 and 3.4 display the aspect of the game during the gameplay.

Figure 3.3: *Maze Game - Home*

Figure 3.4: *Maze Game - Gameplay*

3.3 Game 3 - Sounds

The Sounds Game is designed for children aged 4 to 10 years old.

Description

This game is a playful and interactive way to help children develop key auditory skills. It consists of a nature environment with multiple instruments scattered around it. The player is asked to play a sound and spot the instrument being played in the map.

The primary actions are:

- **Listening** to the sound that is played when the play button is pressed.
- **Identify** the instrument that is currently being played.
- **Find and Select** the previously identified instrument.

The player is successfull when one is able to correctly identify and find the matching instrument for the sound being played. On one hand, when this happens, the player is met with positive feedback such as celebratory sounds. On the other hand, some players may encounter some difficulties and will be met with a negative feedback from the game, in the form of error sounds. As the levels progress, they may increase in complexity with more complex sounds and hard to guess instruments, ensuring engagement and new challenges.

Competences

The Sounds Game helps with the following competences:

- **Auditory Discrimination**- The game helps children sharpen their ability to distinguish different sounds, allowing them to listen carefully and to identify the instrument

being played. It is particularly helpful for children with **Auditory Processing Disorder**, training them to differentiate between sounds.

- **Visual-Auditory Integration**- Children must match the sound they hear with the correct representation of the corresponding instrument in the game. This is helpful for children with **Dyslexia** and **Language Processing Disorder** whose ability to integrate sensory information can be a challenge.

Figures 3.5 and 3.6 display the aspect of the game during the gameplay.

Figure 3.5: *Sounds Game - Home*

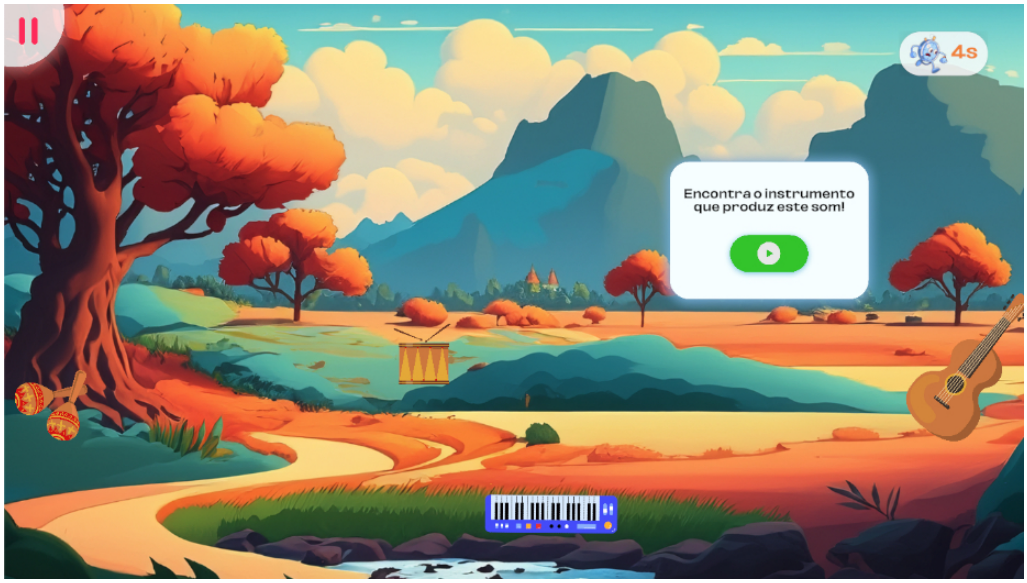

Figure 3.6: *Sounds Game - Gameplay*

3.4 Game 4 - Words

The Words Game is designed for children between the age of 6 and 10 years old.

Description

This game consists of an image and a sequence of characters in which some are blank. The objective is for the player to complete the word with the matching characters.

The primary actions present here are the following:

- **Recognize the image** on the screen.
- **Recognize the word** based on both the image and the displayed letters.
- **Complete the word** by clicking each slot and filling it with each letter.

The player is successful by completing the word correctly. When this is accomplished, a success sound plays and shows the score to the player, encouraging the player to move to different levels. The player fails when is not able to understand which word the image refers to and therefore is not able to complete it.

Competences

The Words game helps with the following competences:

- **Spelling and Vocabulary Building**- Completing words based on given images provides the children a chance to expand their vocabulary. This competence is really valuable for children with **Dysgraphia** and **Dyslexia**, that often struggle with new vocabulary and spelling.
- **Memory**- Playing the game and completing words requires the players to use their memory to recall words, strengthening the ability to remember information. This is particularly valuable for children with **Dyscalculia**.

Figures 3.7 and 3.8 are screenshots of one of the gameplay.

Figure 3.7: *Words Game - Home*

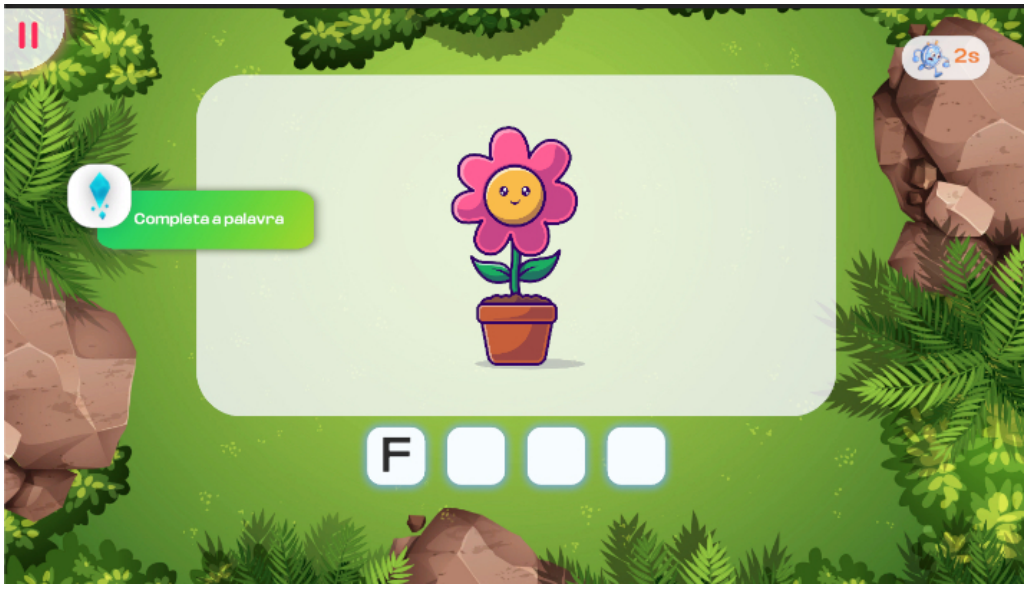

Figure 3.8: *Words Game - Gameplay*

3.5 Game 5 - Puzzle

The Puzzle Game is designed for children aged from 5 to 12 years old.

Description

In the Puzzle Game, the user has multiple levels each one with different images related to ecology. The player can choose the difficulty level to play. The difficulty levels are: Easy, Medium, and Hard (3x3, 4x4, 5x5). Inside the game level the player will have a small window with a view of the completed puzzle, as well as a puzzle section composed by the puzzle table and a tray with puzzle pieces. The objective is for the player to drag the puzzle pieces present on the tray and to drop them in the puzzle table in the correct places. After reaching the end of the puzzle, the game plays a success notification to let the user know it's correct.

The primary actions are:

- **Analyze the image** of the puzzle.
- **Place the pieces** from the tray on the puzzle table.

The score is measured like other games, with a timer. There's no time limit, so success would be for a child to complete the puzzle as fast as possible. Failure can also happen, although no time limit is applied. This may happen when the player struggles too much with the placement of the pieces in the right place and gives up. In this case, it's suggested that the player should choose an easier level.

Competences

The Puzzle Game can help with the development of the following competences:

- **Fine Motor Skills**- Dragging and dropping the pieces into place can require precise control of fine motor skills. This is mostly important for children with **Dysgraphia** and **Visual Motor Deficit** who struggle with motor coordination tasks.
- **Problem Solving and Critical Thinking**- When solving each puzzle, children are encouraged to think critically about the correct placement of each piece. They are forced to analyze and match each piece to its corresponding place. This is beneficial for children with **Dyslexia** and **Dyscalculia** that are challenged in cognitive processing.
- **Patience**- Completing a puzzle can require a lot of patience and the ability to handle small frustrations, when something doesn't go the way we want it to go. This is a valuable competence for all children but particularly for children with **Non-Verbal Learning Disabilities**.

Figures 3.9 and 3.10 represent the gameplay of the Puzzle Game.

Figure 3.9: *Puzzle Game - Home*

Figure 3.10: *Puzzle Game - Gameplay*

4 Game Development

This chapter addresses the technical details chosen to develop the mini-games. Before and during the creation of the mini-games, it is important to correctly detail the looks as well as the tools and technologies used to generate the best architecture. Section 4.1 will start by focusing on the design principles that were taken into account, followed by the technologies used, explaining each choice in the section 4.2. Section 4.3, explains the Unity components in detail. To create these many mini-games a good foundation is needed hence the reason for clear modelling of the software before hands-on work. Section 4.4 will go through an overview for the proposed arquitecture that will be utilized in every game.

Finally, we will be able to see the each game's implementation on its own from sections 4.5 to 4.9.

4.1 Design Principles and Accessibility Considerations

Design is a huge aspect of games, specially the ones being developed in this project. In order to help children with Learning Disabilities, not only the games structure have to be well written but their visuals have to encourage children to learn and play the games.

This section aims to describe the game's structure design. We'll specify each aspect of the game regarding the following topics: **Colors**, **Dimensional Structure** (2D or 3D), and **Style**.

Color

The colors have to be carefully chosen, not only for the game to be more exciting for the players, but also, in this specific case it has to be tailored specifically to children with learning disabilities. For this, we maintain a **high contrast for clarity** across all games, meaning that all colors have a high contrast between the background and the objects. This is a highly important characteristic as it can help children with Visual Motor Deficit and Dyslexia. At the same time, it is also very important to keep a **soft and calming palette** of colors creating a non-overstimulating environment. This can benefit children with **Dyslexia**, **Visual Motor Deficits**, and **Non-Verbal Learning Disabilities**, reducing visual stress and enhancing their ability to process visual information.

Dimensional Structure

As previously seen, the games where all build using a 2D structure. While the developing of a game for children with learning disabilities in 3D is possible, it can never be compared to the decrease in complexity to a 2D environment. 2D games are generally of more **simple navigation and interaction**. They also keep the presentation of the games more straightforward removing the necessity for more details.

Style

There are several types of styles such as: Realistic, Minimalistic, Retro/Pixel-Art, Cartoonish, etc. It's important to note that the mini-games should follow only one style. A **consistent art style** lets the children to know what to expect, while too much change in the visuals might be too overwhelming for children with **Language Processing Disorder**, as consistency helps reduce cognitive load.

The chosen style was the **cartoonish**, which helps provide an enganing and friendly environment for children. Simple characters like animals, hearts, or flowers increase **emotional engagement** and create a playful environment.

Because it is **simple and clean**, this style also helps remove any visual clutter that can be distracting or confusing, making it easier to focus on the task at hand and generating an immediate understanding of each game [3].

With this in mind, it is important to know where to get images and assets for the development of the mini-games. Nowadays, most of the assets found online are protected and

can't be used in public domain. Despite this, some assets for the games have been found online and certified that they can be used in a project context. For this purpose, we used the websites like **Icons8** (`www.icons8.com`) and **FreePik** (`www.freepik.com`).

All other assets are composed with the use of Artificial Intelligence (excluding some developed locally) with the help of Adobe's AI tools in Adobe Photoshop. All the backgrounds for the mini-games have been generated with AI, allowing for commercial use [18].

Design Overview

Before detailing each game, it is important to develop the flow for each one. The games can be rather different from one another, but to keep the same language between all of them we utilized the following flow. When the player opens a game he/she will be greated with a home page with all the necessary instructions to be aquanted with the current game. After this, each game will always have some kind of different levels or difficulties to choose from. Because of this, the folowing wireframes were made, depicted in figures 4.1 and 4.2. After these screens the game shall begin.

Figure 4.1: *Game Home Page Wireframe*

Figure 4.2: *Levels Page Wireframe*

4.2 Methodology, Tools, and Techniques

There are many ways to go about building a game, a lot of frameworks, tools, programming languages, etc. The first decision made was to use an existing game engine that already exists. A **game engine** is a tool that allows the creation of video games without the hassle of building everything from the ground up. This means that any types of assets such as textures, sounds, UI, are already available to use and there is no need to create any type of mechanism to place something on the screen for instance, it abstracts most of the technical details making so that the developer is able to use it and create games in much less time. There are a few game engines that are free to use such as Unity [42], Unreal Engine [9], Godot [23], Game Maker [46], LibGDX [48], among others. It is important to understand what are the main characteristics of the games and to narrow the options based on that. Here we're looking to build 2D mini-games that are not graphically demanding and that can easily be ported to PC, MacOS, Android, or iOS.

It was decided to use Unity due to its support of lots of features regarding 2D game development, the ability to build to almost any platform and also already having quite some experience with the tool.

Because the mini-games have impact on the users through user experience it is also an important step to choose the tool used to prototype every screen present in the game before any development. For that, we will be using Figma [10], a free prototyping tool owned by Adobe that will allow for creating the best scenarios for each screen present in the project. There is also the possibility to ask for feedback from friends and family right before the development, ensuring that almost no time is spent changing layouts or user flows.

4.3 Unity Components

Unity uses the C# programming language to manipulate the game structure but it can also be used with visual scripting. C# is an Object-Oriented Programming (OOP) language so it's great for creating a good architecture using principles like polymorphism, encapsulation, inheritance, and abstraction.

Unity uses a script like system in which every asset that is present in the scene is called a **GameObject** and through these we can introduce C# scripts that will then manipulate the logic in the game. Each script acts as a component of the GameObject and is required to extend the base class *MonoBehaviour* from the Unity Engine's library [38].

This class offers the support for multiple event functions [40], such as:

- **Regular Update Events** - Update functions are frequently called in order to update each object state before rendering the next frame. The main function is the *Update()* function, but there is also a *FixedUpdate()* that updates in discrete time steps in a similar way to the frame rendering.
- **Initialization Events** - These events are called in the initialization of objects. The *Start()* function is called right before the first frame update. There is also the *Awake()* function that is called for each object when the scene is loaded.
- **GUI events** - Graphical User Interface events are also available to handle user interactions. Some of these events are the *OnMouseDown()*, *OnMouseOver()*, and *OnMouseExit()* events that help detecting mouse events.
- **Physics events** - Physics events are also available to detect collisions and triggers such as *OnCollisionEnter()*, *OnTriggerEnter()*, *OnCollisionExit()*, and *OnTriggerExit()*.

There are also objects that can exist independently of GameObject such as the ***Scriptable Object***. Classes that extend this base class are used to centralise data to facilitate access from scenes and assets within a project [39].

4.4 Architecture Overview

Since C# is an OOP language, we have the possibility to use all the principles found in this paradigm such as:

- **Inheritence** - The ability to have an object that inherits it's base from a super component (eg the object Truck can inherit characteristics from Car).
- **Encapsulation** - The ability of hiding the internal state of an object from the consumer.
- **Polymorphism** - The ability to have operations with a given name, that perform the same operation in different ways.
- **Abstraction** - The ability of hiding complexities and implementations exposing simpler objects.

Using these simple principles, the output is easier to understand with less entropy in the creation as well as debugging of the project. It also helps reusing code that can be used multiple times.

The implementation will be contained in a package called **minigames**. Here we can expect a package for each mini-game (**hearts**, **maze**, **sounds**, **puzzle**, and **words**) but also another one for the game home scene that will also require some implementation. Lastly, there will be a package called **common** which will handle any type of operations that can be used for multiple games. An example could be a counter that can be used in multiple games and has the same implementation in all of them.

The implementation can be found in the following Azure Repository: `https://dev.azure.com/A45414/_git/Thesis%20Children%20Learing%20Disabilities`.

Figure 4.3 shows the package structure.

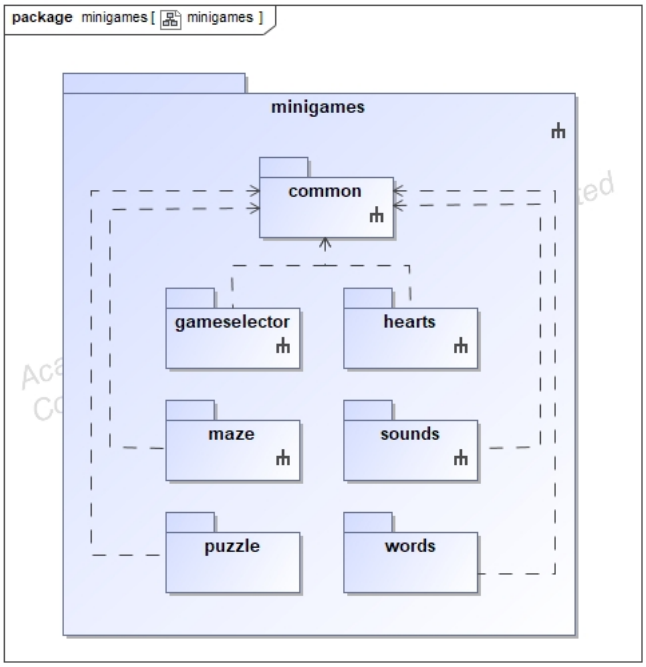

Figure 4.3: *Overall Application Architecture*

The idea is to develop a common structure which will be used by the five mini-games making it easier to create each one with the same structure.

It will consist of abstract handlers that contain a small chunk of implementation that applies for all games. This solution design aims at reducing entropy and ambiguity as much as possible, allowing for the developer to focus solely on each game development one by one.

The main components for this architecture are as follows:

- ***GameHandling***.
- ***MenuHandling***.
- ***ScoreManager***.
- ***ScenesHandling***.

GameHandling allows for a variety of operations, but it mainly allows the game to support basic funcionalities such as:

- Start and finish game.
- Exit and restart game.
- Managing game state.

Because we're using Unity where most of the scripts will be attached to GameObjects and not directly connected to these mechanisms, *GameHandling* hosts two separate events capable of notifying components of Start and Finish game events.

It utilizes the Observer Design Pattern [14] which allows the definition of a subscription mechanism to notify multiple objects about these events on the game status [11].

GameHandling is also responsible for loading the game and therefore has an unimplemented method 'LoadDifficultyLevel' which after implementation is able to load any game. It's important to notice that each game may have it's definition of a difficulty level and for that reason this object allows for any time of level needed.

MenuHandling is responsible for user interaction with game menus such as 'levels menu', 'scores menu', and 'pause menu'. It has two important methods 'HidePanel' and 'OpenPanel', able of opening and closing any menu with an expanding animation. On these methods, the developer should specify all the menus and interactions they should have. It contains several operations that are present in all the games such as:

- Dealing with the choosing Levels Menu ('OpenLevelMenu', 'HideLevelMenu', 'GoBackToGameButton').
- Opening and closing the audio settings ('OpenAudioSettings', 'CloseAudioSettings')
- Dealing with the end of a game ('ShowScoresFinish', 'OpenGameFinishOptions')
- Reading instructions out loud ('ReadInstructionAloud', 'StopInstructions', 'PlayAudioSequentially')

It keeps a reference to the 'GameHandling' (generic objects 'T' and 'V') and the 'ScoreManager' (generic object 'A' means the type of the score) of the game and if necessary performs changes.

ScoreManager is an abstract component that holds and saves the game scores. It is created once in the 'GameHandling' object. It has several operations that allow for the setting and getting of the scores. Because scores can differ between mini-games, the score itself only has the constraint of being an object that implements the C# Interface *IComparable*, allowing multiple scores to be compared.

Because the 'MenuHandling' and 'ScoreManager' need to be accessed at any time from any Object, the Singleton pattern was considered [15]. This is a design pattern present

in object oriented programming languages and ensures that a class has only one instance, while providing a global access point to the instance [11].

ScenesHandling is a static data object that stores all the names of each mini-game as constants, removing ambiguity while navigating between scenes from anywhere.

Figure 4.4 represents the complete architecture of this mechanism in UML.

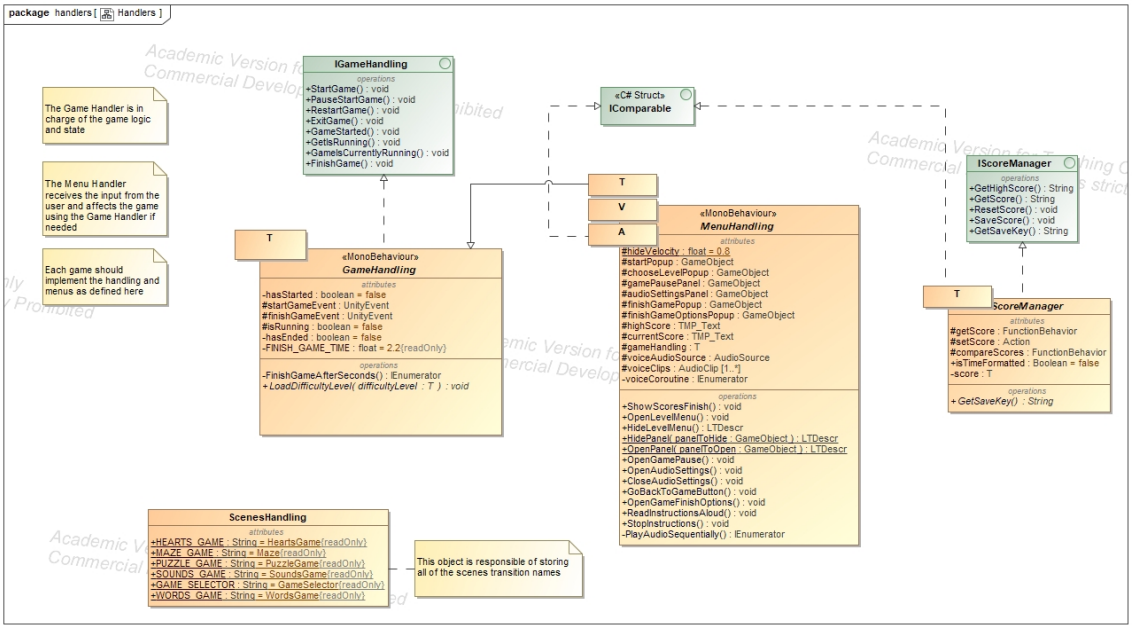

Figure 4.4: *Handlers Mechanism UML*

Common The 'Common' package hosts as the name implies all objects that although not being a part of the architecture can help simplify the process of development of the games. At this stage, only two classes were needed.

The 'Counter' behaviour will be used across multiple games. It is started through each GameHandling and, is able to communicate directly with the 'ScoreManager'. This enables the counter to increase time through the 'ScoreManager' object and update the correspondant UI.

The 'AudioSettings' behaviour handles the Audio Settings user interactions. It has access to all the Sliders in the Audio Menu (a slider is an existing Unity GameObject), each one is matched with a different mixer group. In Unity audio is handled with Mixers. The way the games were set up, each one has a mixer. Inside each mixer we can define multiple groups. Multiple groups were created for each game depending on the audio played, such as 'Voice', 'Background Music', 'Notifications'. This allows each group to be controlled separately and also has the ability of adding audio filters for each one (such as low or high pass filters).

'ButtonAnimation' is a behaviour that is used in all of the games that set an expand and collide animation for the buttons in the game. Just like the rest of the UI does, it utilizes the 'LeanTween' external library for best results.

The 'SetScaleZero' is an object that helps the developer work on any UI component without

having to worry about leaving everything as it was before. This class sets visible only the game start UI components, keeping all others hidden.

Figure 4.5 depicts the common package in UML.

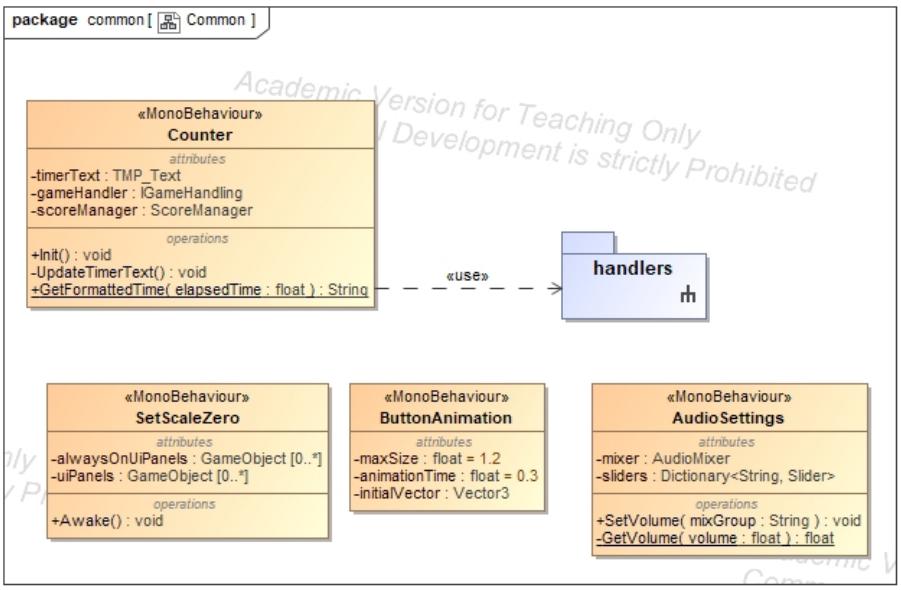

Figure 4.5: *Common Package UML*

4.5 Game 1 - Hearts

The first game to be developed is the Hearts game, designed for young children between the age of 6 to 10 years old.

A significant entity in this game is the heart object that, as previously stated, may have different types and each one has a different impact on the scoreboard. For that, the ScriptableObject interface [39] comes in handy. This gives us the possibility of parametrizing each Heart to a as well as a lifespan of that type of heart along with the score.

Another important aspect to tackle is the game settings. What this means is to parametrize the game into different difficulties so that the player can advance through each level as they learn along. For this, we will also be using the ScriptableObject interface, taking into account the following aspects:

- Spawn rate of the hearts on the screen.
- Type of heart to be spawned followed by the probability of that heart to be spawned.
- Time of the challenge.

These objects allow us to directly create a heart in the Unity Editor and attach the different characteristics we want for it. The same goes for the Game Settings, which makes it easier to change the level of the game or even add another one.

Every heart to be instantiated in the game has a behaviour. In this case, it has to affect the state of the game score and be immediately destroyed afterwards. This is handled through

the 'HeartScript' that is composed of a **Heart**.

To update the score, there is an implementation of the **ScoreManager**, the ('HeartScore-Manager') that keeps track of the score as an integer.

Another problem to tackle is the random spawning of hearts. Any object to be instantiated will be a GameObject and therefore there needs to be a script to handle this behaviour. 'HeartSpawner' is in charge of this, making sure to use the GameSettings to spawn each heart on the screen at different speeds and types of hearts.

Lastly, there is the 'Bar' class used for handling the behaviour of the timer that advances according to the time boundaries of the game. This is done using *LeanTween*, an extension of the Unity library that can be used to animate assets.

The following UML diagram (Figure 4.6) describes the Hearts game architecture.

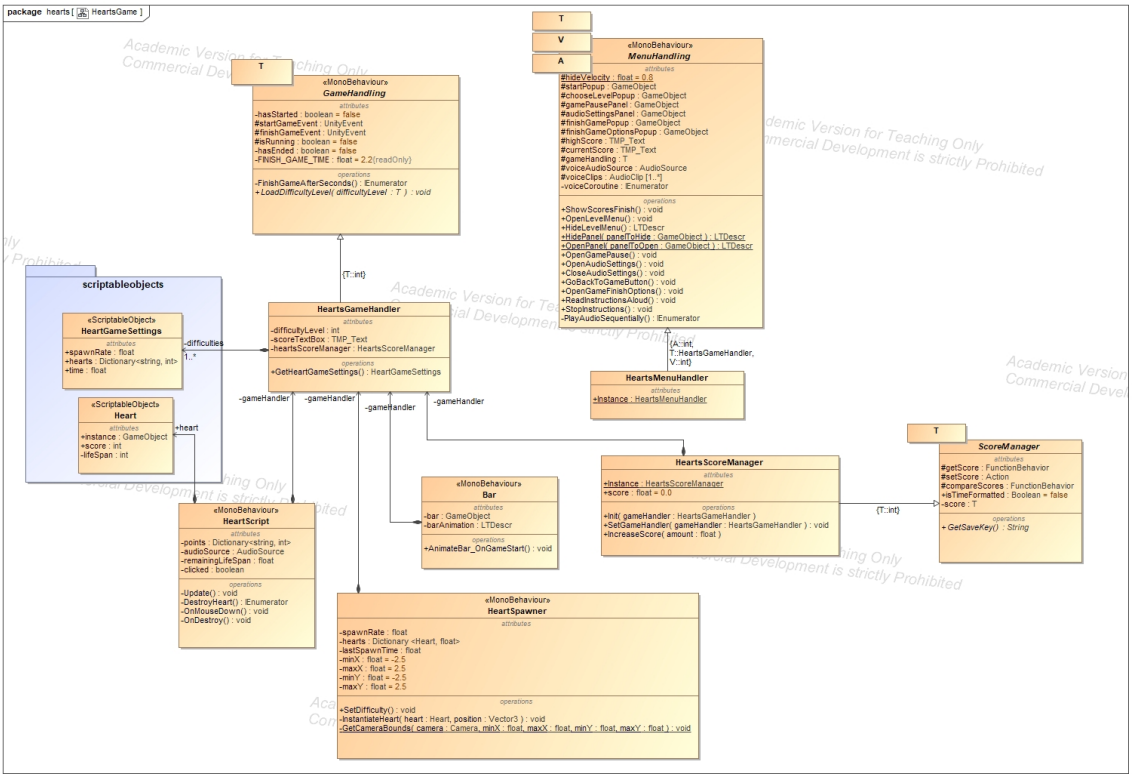

Figure 4.6: *Hearts Game entities - UML*

4.6 Game 2 - Maze

The following UML of Figure 4.7 represents the Maze Game arquitecture.

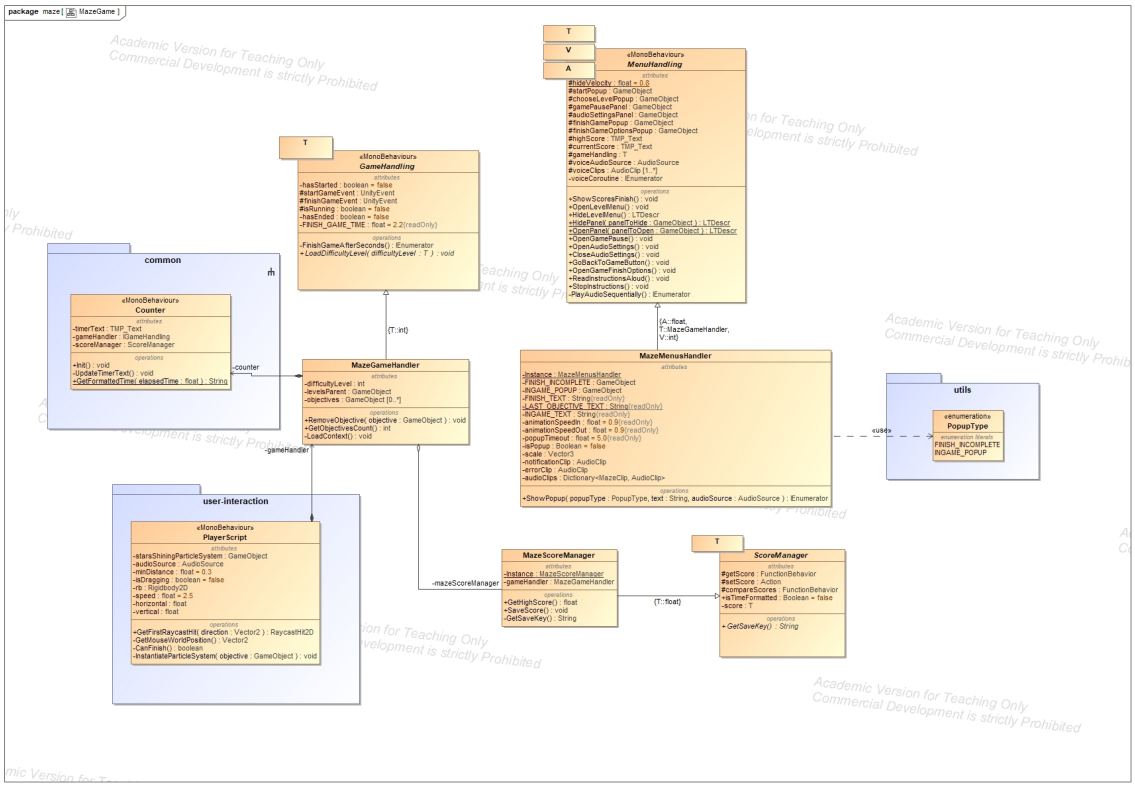

Figure 4.7: *Maze Game Entities - UML*

The Maze Game consists of a map with a maze and multiple objectives the user has to attain before reaching the end of the maze. There are a couple of aspects to tackle.

The game has multiple levels, each one designed directly in Unity. The levels have inside the maze many objectives the player has to accomplish. For that, we utilized Unity's ability to tag GameObjects. Each objective has a tag and the player will play a certain logic given the tag of the catched object. All the objectives will be stored in a List structure and will be deleted as the player collects objectives.

The player movement is such that the user can have a choice of dragging the character through the path or using the Up, Down, Left, Right combination on the keyboard. All this logic is present in the 'PlayerScript' behaviour located right at the player GameObject. The 'PlayerScript' utilizes many 'MonoBehaviour' methods such as 'OnMouseDown', 'OnMouseUp' and 'OnTriggerEnter2D' to detect user drag and drop actions and player collision with objectives. It comunicates directly with the 'GameHandling' to trigger finish events and update the game state.

There were also some popups implemented so that the user can get a notion of how the game is going. If the player tried to escape the maze before collecting all the objectives, this throws a popup reminding the player to go back, for example.

Lastly, the 'Counter' was used to assess the time as score measurement and was directly wired to the implementation of 'ScoreManager' ('MazeScoreManager').

4.7 Game 3 - Sounds

The Sounds Game structure is as depicted in Figure 4.8.

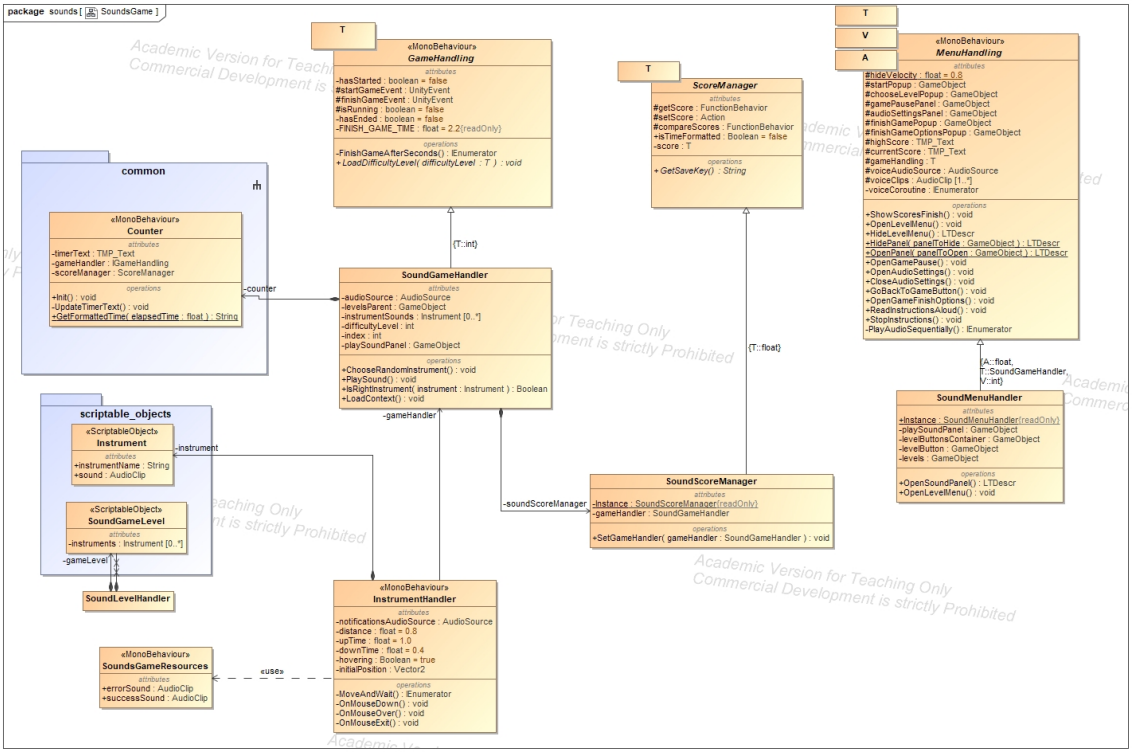

Figure 4.8: *Sounds Game Entities - UML*

The Sounds Game's purpose is to let the player hear and find the instrument that is playing.

The are several levels in this game. Each one was created before hand, and consists of a map (background image) and multiple instruments scattered around this map. The player has a play button where one can play the instrument; after this, the game begins. The music starts and the player can hover over the instruments on the floor when once finds the correct one, one can click on it.

Each instrument on the floor was mapped to a *ScriptableObject*, *Instrument* which stores the instrument's name and its Sound, as an *AudioClip* (*Unity*'s implementation of audio objects). This Object is stored into the instrument's own handler, *InstrumentHandler*, that utilize's *Unity*'s mouse events to detect mouse clicks and hovering. This way, the handler can trigger *LeanTween* animations. This object is also responsible of comunicating the *SoundGameHandler* of which instrument is being clicked.

Each level was also mapped to a *ScriptableObject*, *SoundGameLevel* which hosts a list of all instruments available inside its level. All levels are present in the game scene inside a parent GameObject (all levels start disabled).

The *SoundGameHandler* is the handler of this game and is able to load a certain level by accessing the parent object (*levelsParent* attribute) and loading a certain level, gathering all its instruments to the attribute *instrumentSounds*. It has a method capable of validating if the right instrument is being clicked *IsRightInstrument* (triggered by *InstrumentHandler*).

This object also plays the instrument's sound for the player to listen.

This game's score metric is also the *Counter* from previous games, being again instantiated by the game handler.

4.8 Game 4 - Words

The Words Game architecture is depicted in Figure 4.9.

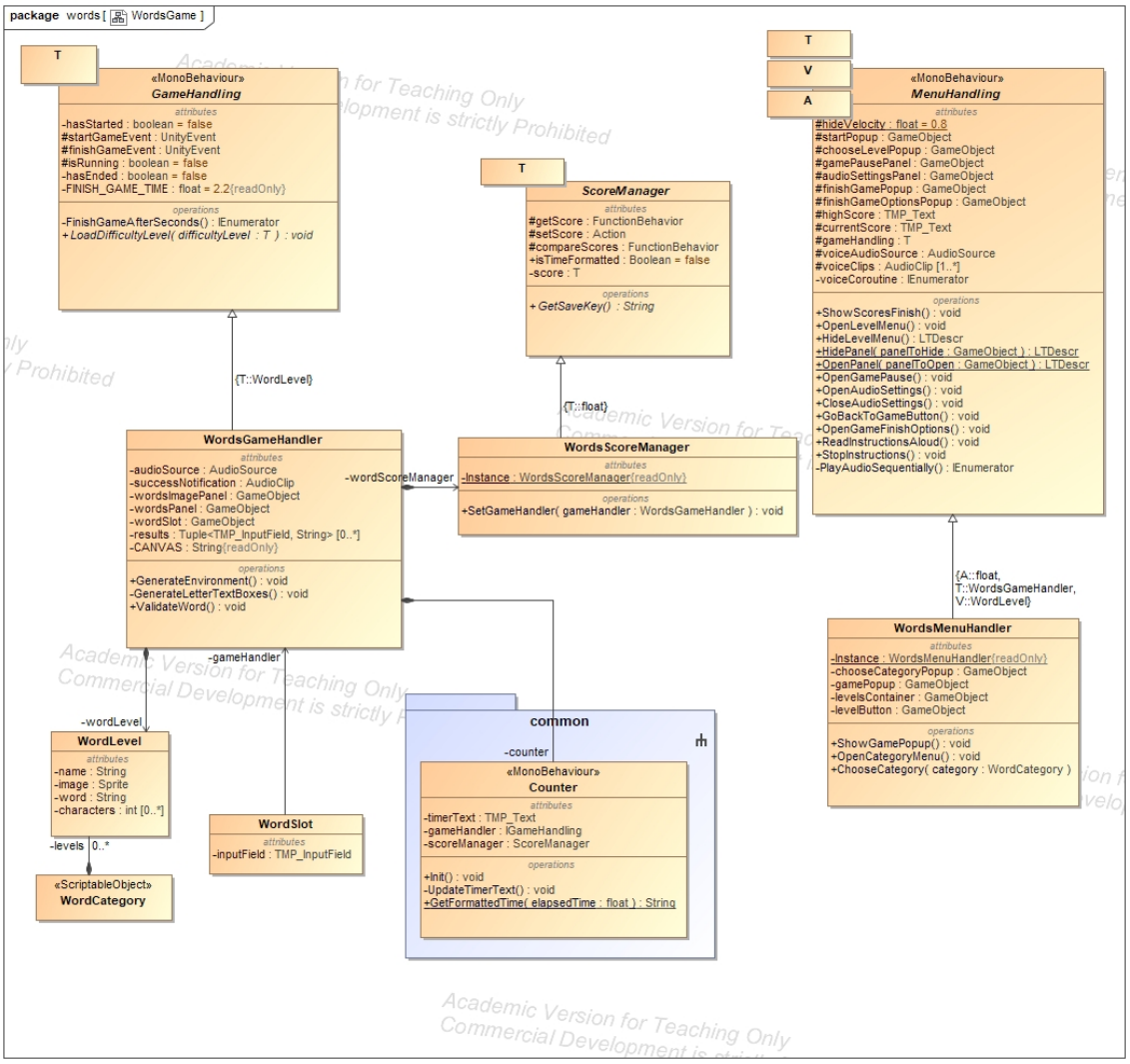

Figure 4.9: *Words Game Entities - UML*

This game's purpose is to find the word that describes the image being displayed. Like defined before, there are two categories for these images: *Nature Objects* and *Industrial Objects*.

Each game category was mapped to a *ScriptableObject* which is composed of multiple levels inside. Each level is a *Word Level* that is also a *ScriptableObject*. Each *WordLevel* has a name, an associated image, a complete word and a list of characters that define which characters are visible and which ones aren't.

The *WordsGameHandler* is capable of generating an environment (*GenerateEnvironment*

method together with *GenerateLetterTextBoxes*) from this *WordLevel* alone. This environment is an UI that has the current word's image and multiple text box slots where the player can type the word according to the image (some slots come pre-filled depending on the *WordLevel* hiding *characters*).

Each slot was also assigned to a *WordSlot* object, that it's main responsability is to validate the word every time any Word Slot text changes. For this, it utilizes the *WordsGameHandler*'s *ValidateWord* method.

The GameHandler also uses the *Counter* as a score metric, being stored as a float in the *WordsScoreManager*.

4.9 Game 5 - Puzzle

The Puzzle Game was defined as depicted in Figure 4.10.

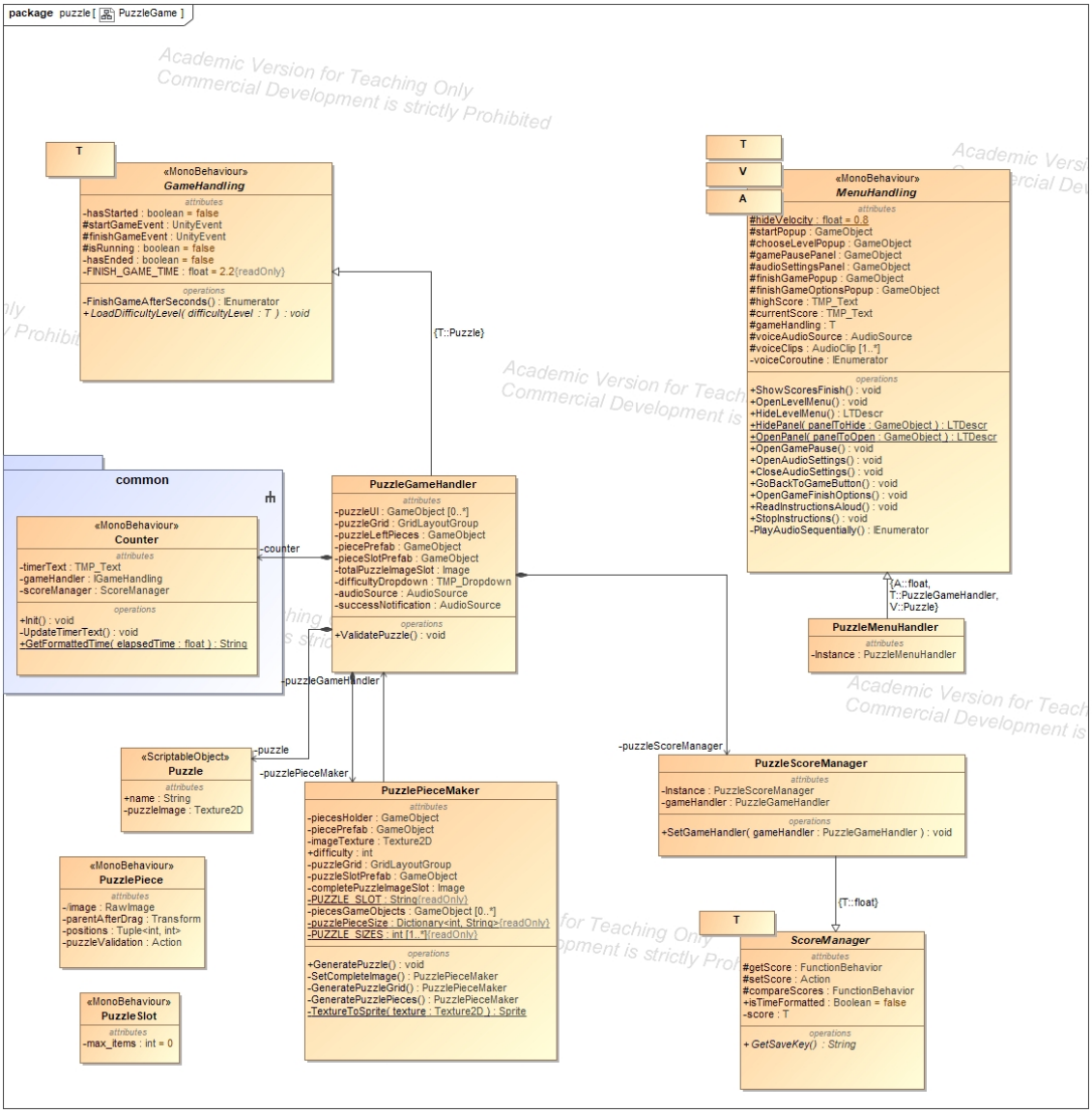

Figure 4.10: *Puzzle Game Entities - UML*

The purpose of the game is for the player to complete puzzles. The first aspect defined was

how it would be played. After some thinking, the best way to do it would be with three main components on the screen:

- Complete Puzzle Image.
- Puzzle Grid to place pieces.
- All puzzle pieces in a tray.

The grid and the tray both used Unity's UI grid layout group, which is a component that organizes its children in a grid-like way. The puzzle grid would have multiple placeholders (each placeholder is a 'PuzzleSlot') for the puzzle depending on the difficulty (3x3 or 5x5 grid for instance).

The player has to be able to drag and drop pieces from the tray to the placeholders on the puzzle grid. This mechanism utilizes Unity's methods 'OnBeginDrag', 'OnEndDrag', 'OnDrag' from the IBeginDragHandler, IDragHandler, and IEndDragHandler interfaces.

For faster level creation it was also decided the game itself has to be able to cut any image into puzzle pieces. This way, we can introduce new levels to the game by simply adding an image.

All these functionalities are present in the 'PuzzlePieceMaker' class with the following methods:

- SetCompleteImage.
- GeneratePuzzleGrid.
- GeneratePuzzlePieces.

This object is used in the game handler ('PuzzleGameHandling') and uses the 'Puzzle' object, a 'ScriptableObject' that holds each puzzles name and texture image.

Like some other games, this one also uses the 'Counter' mechanism as a way to store scores in its 'PuzzleScoreManager'.

5 Experimental Evaluation

In this chapter, we report on the experimental evaluation of our games.

These games were designed to help children with specific learning disabilities like dyslexia, dyscalculia, and other challenges. Section 5.1 showcases the evaluation process and limitation such as the tests not being made with children diagnosed with LDs.

The aim of section 5.2 is to understand how well these games engaged the children, supported their learning, and addressed their difficulties. This section is partitioned, according to the games tested, ending with a discussion on the overall results obtained.

5.1 Evaluation process and limitations

For these studies, tests were conducted for the five minigames developed in this project, with the help of the teachers, Salomé Alves and Ana Cardoso, from the school EB1/JI da Portela, Lisbon. This school has students from the first to fourth grade, having children between the ages of six to ten. The testing scenario was done in the Class 1A, correspondant to the first graders. The teachers played an essential role in coordinating the testing sessions, ensuring the children understood the instructions, and providing support throughout the process. They contribute insights into practical challenges and effectiveness, making the games more relevant for classroom [13].

Originally, the goal of this evaluation was to assess children with diagnosed LDs. Unfortunately, this was not possible. Due to several factors, it was not possible to reach a large enough group of children with LDs. Some of the challenges include the limited access to specialized schools and restrictions to obtaining parental consent for participation. We decided to carry out a test scenario with a broader group of children.

Despite the children in the current study not necessarily having LDs, it still provides us with valuable insights on the developed project. The games share similar design, interactions, narratives, and levels. The feedback received from the children, helped identify issues also affect children with LDs, such as the need for clearer instructions, and the effectiveness of visual aspects of the game. This feedback is directly applicable to refining all five games.

Two tests were conducted in both July and October of 2024. As the games were not all ready in July, the first round of tests only included the Hearts Game, the Maze Game, and the Puzzle Game. Only the second round included the other two games (Sounds Game and Words Game). As there were two rounds of tests, we were able to fix or add functionalities from the first one to be tested again in the other tests.

Moreover, many of the challenges observed, like motor coordination problems and the difficulty some children had in focusing, are issues that are also commonly faced by children with LDs. With this in mind, the problems identified and the corresponding suggestions for improvement are relevant to the target group in mind.

5.2 Results

In this section, we report performed in the classroom. It's important to notice that, for each game, data was gathered in two batches. The first one was the observing of the children during the gameplays and even small conversation while the children is playing the game. The second and last part was a small post interview to gather feedback from the children such as pros, cons and some observations the children might have.

The informations retrieved were the following.

Gameplay

- Difficulties
- Game Score

- Quality
- Is the game easy?
- Comments
- Socializing
- Observations

Feedback

- Did you like the game?
- Are levels hard?
- Did you like all the levels?
- Did you like the stories?
- Was it hard to understand what to do?
- Did you learn anything?
- Could it be more fun? How?
- Would you like to play it everyday?
- Do you want to play it with friends?

5.2.1 Maze Game Results

The game had players move Mr. Pig through a maze, collecting items before finding the exit. As players moved to higher levels, the mazes got bigger and more complicated.

Many kids found the controls difficult. Some had trouble using the mouse, especially on higher levels. Others breezed through the early stages but struggled with the harder ones later on. This shows that while some levels were too easy for certain kids, others were quite challenging. Comments like “move, pig” and “the little pig doesn’t want to go” were common, highlighting how character movement was tricky for some children. It suggests that using the mouse was a major obstacle for many of them.

Despite some difficulties, most children said they enjoyed the game. Many of them were enthusiastic, with responses like “yes, I would play this game everyday”, being common. However, there were also some suggestions for improvement, such as making Mr. Pig move faster or simplifying the controls.

Overall, the Maze Game was engaging for the kids, though it highlighted issues with motor coordination, especially for those using a mouse. This shows how important it is to simplify controls for children who have motor skill challenges. The narrative—about Mr. Pig cleaning up the garbage—seemed to resonate well with the children, which kept them motivated despite the control issues.

After this assessment, the game’s control, that was previously done just with mouse drag and dropping, was changed allowing for the users to play with the ’WASD’ keys or arrow keys. This was done so that, if movement with the mouse is tricky the user can use other options.

During the second round of tests we noticed that the children maintained similar interest levels, with children excited to play. Nevertheless, some players found the game either too easy or too challenging. This might suggest the designing of some new levels with other difficulties. Based on observations, there was a better understanding of the games mechanics but there were still some children who had difficulties understanding them. This is something to think of when refining the game.

5.2.2 Puzzle Game Results

The Puzzle Game featured ecology-themed puzzles with three levels of difficulty to choose from. The players had to place pieces into a puzzle using a tray.

The children’s performance varied widely. Some completed the puzzles quickly, while others needed some assistance. There were also some that showed a lot of enthusiasm, mentioning that he was ”“very good at puzzles”. However, some children, didn’t notice the reference images provided, which might have made solving the puzzles easier for them.

The Puzzle Game seemed to be well received, but it was clear that some children needed more help noticing important visual cues, like the reference image. For this, the reference image was made more obvious with the help of a frame around it, making it clearerer to the users and improving the experience. Figure 5.1 details the new reference image.

Figure 5.1: *Reference Image Frame*

In the second round of tests the popularity of the game was reinforced, with positive remarks on its design. After the inserting of the new reference image frame (fig. 5.1) the spotting for it was a lot clearer and easier for children too understand how it works. Besides the positive feedback there are still ways that can be adopted for a better user experience, such as a different background image that contrasts more with the game elements. Familiarity helped children perform better, though some still felt a little lost with the controls. This issue might be present in more of the games and its solution might be applicable for all games.

Overall, the positive comments and the children's eagerness to play again show that puzzles can be an effective way to develop problem-solving skills.

5.2.3 Hearts Game Results

The Hearts Game was about collecting items and following a story as the levels got harder.

Some children had trouble concentrating and needed help, especially on the difficult levels. One child needed assistance on the third level, which she found tough. A few kids struggled with controlling the game, particularly when using the mouse.

Feedback was mixed. Two enjoyed the game and said they'd like to play it again. Others found it too hard and weren't eager to replay. One mentioned it could be more enjoyable but didn't offer specific suggestions. The story didn't engage everyone; responses varied when asked, "Did you like the stories?".

The game highlighted challenges with control and understanding. The difficulty of some levels and unclear instructions made it less fun for some children. Simplifying the controls and offering more guidance on harder levels may improve the game. However, the positive feedback from others suggests the story aspect could work well with some improvements.

After the second round of tests we could observe some children like the game but complained

about its duration. After reviewing this aspect, we could see that the duration of each level is too short and should be revised. During this round we could also see some difficulties when trying to exit the game before the level was started. This can be a user experience issue and should be addressed. During the first round of tests, some children were upset of how long the story of the game is. This no longer seemed to be a problem, as the stories can be read out loud in the new version.

5.2.4 Words Game Results

The Words Game was designed to test the children's language and letter recognition abilities. The gameplay involved children completing words on the screen related to either "nature objects" or "industrial objects", with each category offering a distinct set of vocabulary. This game aimed to assess their familiarity with words, understanding of word construction, and ability to recognize and place letters accurately.

Children engaged actively with the Words Game, often discussing words with each other and asking peers for help if they found a word difficult. The game fostered collaboration as they compared strategies or took turns attempting words from each category.

Most children found the Words Game to be accessible and enjoyable, particularly those who enjoyed spelling and word games. They appreciated the word categories, which were relatable and easy to understand.

A few children encountered issues with specific words that contain accents in them, such as "Árvore" (tree). These challenges sometimes led to frustration, especially if they felt they had to start over. Despite this being good, because the game aims to improve the vocabulary and grammar, this led us to believe that maybe the order of the words in the levels might not be ordered (from easy to hard words).

The Words Game successfully engaged children in spelling and word recognition tasks, having a positive feedback. Improving the order of the levels from easy to harder, having in consideration factors like, accents and length of the word, could really increase the quality of the experience, allowing children to focus more on word completion rather than technicalities of interface interaction.

5.2.5 Sounds Game Results

The Sounds Game was developed to see how well children could identify and match different sounds with their corresponding instruments. Children first chose the level, listened to sound, and then searched for the right instrument scattered on the screen and clicked it. The goal is to assess not just their listening skills, but also how well they could tell sounds apart even in a noisy environment.

During the game, the children were really interested. They often competed in a friendly way, trying to see who could complete each level the fastest. The time results were recorded to add a bit of competition, which helped keep them engaged. Many of the children interacted with each other while playing, comparing their results and chatting about the different sounds they heard.

When multiple sounds overlapped, some children found it challenging. This was especially true for those with weaker auditory processing skills, who struggled to separate individual sounds from a more layered audio environment. In order to help issues such as the background music being too loud to understand, a new panel was added to the pause menu UI (common to all the games), that provides a slider for each of the sounds playing in the game (background music, notifications). Figure 5.2 represents the new menu added to address this issue.

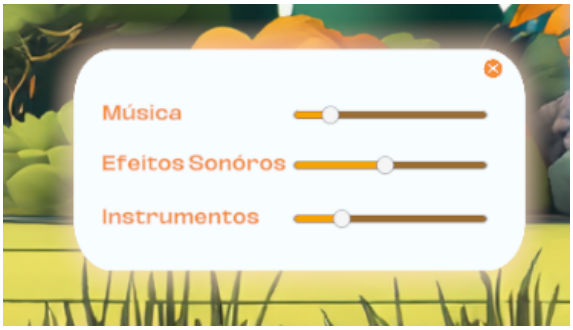

Figure 5.2: *Audio Management Menu*

Overall, the feedback was positive, but there were some areas that could be improved. One suggestion was to make the sound environment a bit simpler. For example, making each sound clearer and reducing noise could help children hear the instruments better. This change would be especially helpful for children who get distracted when there are many sounds happening at the same time. Overall, the Sounds Game kept the players engaged, and having fun.

5.2.6 Discussion

With the results in mind, we can see both success and improvement areas. The children showed a lot of enthusiasm, some wanting to play them regularly. The tests provided us with real feedback such as recurring issues with the control in the Maze Game for instance, that was quickly fixed after simplifying the control schemes. Also the issue with the visual cues provided in the Puzzle Game not being well accessible by some players that was also fixed later on.

The feedback highlighted the importance of engaging content that matches the children's interests, such as ecology and familiar characters. The games did well in capturing their attention and gave the valuable insights into how different game mechanics impact engagement and learning for kids with learning disabilities.

One common thing that happened sometimes was that the children sometimes skipped the games stories and instructions and sometimes had to come back and read it in order to know how to play the games. To simplify this, the reading out loud feature was created and set to read each game's story before starting it, along with a new button that allows for the enabling/disabiling the reading out loud, as depicted in Figure 5.3.

There were also some usability challenges regarding unclear instructions, and interface difficulties in multiple games. To later fix this each game should have in its homescreen an

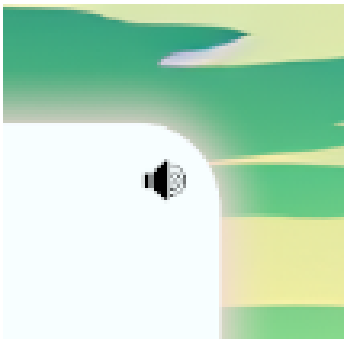

Figure 5.3: *Read out loudInstructions Button*

"Instructions" labeled button that provides a clear understanding of the game mechanics. Another user experience issue, that was found during the Hearts Game testing but can be applicable to any other game was the inability of exiting the game before starting any level. Some children tried clicking the "Pause Game" button and were met with no reaction because the level hadn't actually started. A new input should be added to the games so that exiting could be accessible from any screen. Adding this could enhance the user experience.

The second round of tests was really helpful to gather some more information on the games that were previously tested, as well as some new info on the ones that hadn't yet been exposed to players. With this new round, we found the children really excited, as they were already familiarized with the games. We could also see an improvement on some issues encountered before. Because of this, we gathered more feedback and some features and bugs to tackle in order to better increase the quality.

Overall, the enthusiasm shown by many of the children indicates that educational games have great potential to support learning when they are designed with their needs in mind.

6 Conclusions

The following chapter pretends to summarize the problem, and the proposed solution, providing a clear overview of the path followed to reach the end project that is showcased in this thesis. The results from the testing such as feedback will be sumed and some observations will be made regarding the overall project.

In section 6.1, the future work will be strategized so that the project has more impact over time.

The goal of this thesis was to develop mini-games having in consideration children with learning disabilities. Since the focus group of this project has several distinct disabilities, an analysis was conducted of every single one of them, in order to understand the intersections of the characteristics of these issues, or their differences. The essence of this issue is the segregation of children when it comes experiencing ways of learning. The goal is to give tools to these children, so that they can overcome their challenges, and feel a closer experience of learning as their peers.

To reach an optiomal solution there were several different areas to tackle. After the initial research, the project was separated into multiple parts: the technical architecture, design system and, testing and analyzing.

Before the technical implementation, several aspects had to be defined. This was done carefully using the data gathered from the previous reseach on LDs. With this in mind, some tools were chosen to accelerate the development process, such as using of Unity and Figma.

Mockups were created and discussed with the team, going through several rounds of refinement. This is an extremely important step because it defines a big part of the user experience of the players. This was a great opportunity to step out of the confort zone and learn more about the experience of the players. After all, the experience has to be really well optimized for children with LDs.

With designs in mind, the architecture was developed. The biggest challenge here was to create a system which allows for the creation of multiple games on top of it. For this we used the C# language, an OOP language which supports the four fundamental principles

of OOP (polymorphism, encapsulation, inheritance, and abstraction). With this and some design pricinples such as Observer and Singleton, we're able to write clean and reusable code. Because of this, the proposed solution includes a base that is the "frame" for all mini-games to be built on. This approach was not only used to save time and develop faster, but also to allow for future developments in the software.

Lastly, the tests were conducted. Altough not being tested with children with LD, they really helped understanding what each game was lacking and some points to be improved in the future. The chance of doing two stages of the tests, one in July and another in August, was really helpful as the output from the first stage, which resulted in new features and some bug fixes, was in the input of the second round of tests and we could directly see the impacts.

All these developments, led to the creation of a 2D game, containing multiple mini-games inside it. A game with a cartoonish look makes easy to understand instructions and visual cues, so that children with LDs could experience the best of a learning game.

This thesis project allowed for a better understanding of the effectiveness of games as a tool to help young children learn, including those with specific challenges. Although we were only able to test with three out of the five mini-games, this really helped increasing the quality of the project. The testing phase engaged children and sparked interest, but also raised issues that needed to be accessed.

The task of developing games that target a niche of users allowed for an extense research on the matter. This crossover between multiple areas such as Psychology, LDs, Software Engineering, and User Experience, leads to a product that can be useful.

6.1 Future work

Going forward, some things that would totally increase the quality of the games, would be the access for multiple languages. Right now, the games are tailored to a specific group of children and, the ability to add new levels is quite simple. This is due to the simplicity of the design of the software. Despite this, because these games are to be used in schools and medical centres, the end game is to let the teachers or doctors or anyone assisting the gameplay to children to be able to edit and create a completely different narrative for each children. What can be proposed is a new area to the main menu, where the tutor can manage each game and customize the gameplay. This could include changing the story, icons, and adding or removing levels.

References

[1] "Article on Dysgraphia". In: *PMC* (2023). Accessed: 2024-11-04. URL: https://pmc.ncbi.nlm.nih.gov/articles/PMC7082241/ (cit. on p. 21).

[2] E. Bloom and N. Heath. *Recognition, expression, and understanding facial expressions of emotion in adolescents with nonverbal and general learning disabilities*. 2009. URL: https://pubmed.ncbi.nlm.nih.gov/19843659/ (cit. on p. 17).

[3] L. J. Brady. *Apps for Autism: An Essential Guide to Over 200 Effective Apps for Improving Communication, Behavior, Social Skills, and More!* BookBaby, 2012 (cit. on p. 42).

[4] *Characteristics and Signs of Dyslexia*. 2023. URL: https://www.fcps.edu/academics/academic-overview/special-education-instruction/high-incidence-disabilities-team-k-12-2 (cit. on pp. 8, 9).

[5] Child Development Australia. *Visual Perception Concerns in Child Development*. Accessed: 2024-11-04. 2023. URL: https://childdevelopment.com.au/areas-of-concern/visual-perception/ (cit. on p. 27).

[6] C. Clinic. *Dysgraphia*. Accessed: 2024-11-04. 2023. URL: https://my.clevelandclinic.org/health/diseases/23294-dysgraphia (cit. on pp. 20, 21).

[7] C. Clinic. *Dyscalculia: Symptoms and Causes*. 2024. URL: https://my.clevelandclinic.org/health/diseases/23949-dyscalculia (cit. on pp. 14, 15).

[8] Edutopia. *What Teachers Should Know About Dysgraphia*. Accessed: 2024-11-04. 2023. URL: https://www.edutopia.org/article/what-teachers-should-know-about-dysgraphia (cit. on p. 21).

[9] Epic Games. *Unreal Engine*. 3D creation platform for game development and other real-time applications. 2024. URL: https://www.unrealengine.com/ (cit. on p. 43).

[10] Figma. *Figma: The collaborative interface design tool*. Accessed: 2024-11-04. n.d. URL: https://www.figma.com (cit. on p. 44).

[11] E. Gamma, R. Helm, R. Johnson, and J. Vlissides. *Design Patterns: Elements of Reusable Object-Oriented Software*. Boston, MA: Addison-Wesley Professional, 1994. ISBN: 978-0201633610 (cit. on pp. 47, 48).

[12] GraphoGame. *GraphoGame*. 2023. URL: https://graphogame.com/ (cit. on p. 29).

[13] K. Guldberg, S. Parsons, K. Porayska-Pomsta, and W. Keay-Bright. "Challenging the knowledge-transfer orthodoxy: Knowledge co-construction in technology-enhanced learning for children with autism". In: *British Educational Research Journal* 43.2 (2017), pp. 394–413. DOI: https://doi.org/10.1002/berj.3275. eprint: https://bera-journals.onlinelibrary.wiley.com/doi/pdf/10.1002/berj.3275. URL: https://bera-journals.onlinelibrary.wiley.com/doi/abs/10.1002/berj.3275 (cit. on p. 58).

[14] R. Guru. *Observer Design Pattern*. Accessed: 2024-11-04. n.d. URL: https://refactoring.guru/design-patterns/observer (cit. on p. 47).

[15] R. Guru. *Singleton Design Pattern*. Accessed: 2024-11-04. n.d. URL: https://refactoring.guru/design-patterns/singleton (cit. on p. 47).

[16] Hearing Health Foundation. *APD Demographics*. Accessed: 2024-11-04. 2022. URL: https://hearinghealthfoundation.org/apd-demographics (cit. on p. 23).

[17] M. Hearst. *6 Surprising Ways Nonverbal Learning Disability Affects Me as a Young Adult*. 2024. URL: https://www.understood.org/en/articles/6-surprising-ways-nonverbal-learning-disability-affects-me-as-a-young-adult (cit. on p. 17).

[18] A. Inc. *Adobe Generative AI User Guidelines*. 2024. URL: https://www.adobe.com/legal/licenses-terms/adobe-gen-ai-user-guidelines.html (cit. on p. 43).

[19] A. of JAMA article. "Nonverbal Learning Disabilities: Impact and Interventions". In: (2024). URL: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2764298 (cit. on p. 17).

[20] K. Kelly. *Classroom Accommodations for Nonverbal Learning Disabilities*. 2024. URL: https://www.understood.org/en/articles/at-a-glance-classroom-accommodations-for-nonverbal-learning-disabilities (cit. on pp. 18, 19).

[21] KidsHealth. *Central Auditory Processing Disorder*. Accessed: 2024-11-04. 2023. URL: https://kidshealth.org/en/parents/central-auditory.html (cit. on pp. 23, 25).

[22] G. Learning. *Fast ForWord Program*. 2023. URL: https://www.gemmlearning.com/programs/fast-forword/ (cit. on p. 28).

[23] J. Linietsky and A. Manzur. *Godot Engine*. Open-source game engine for 2D and 3D games. 2024. URL: https://godotengine.org/ (cit. on p. 43).

[24] A. Magazine. *Language Processing Disorders: Recognizing Symptoms*. 2024. URL: https://www.additudemag.com/language-processing-disorders-recognizing-symptoms/ (cit. on pp. 11, 12).

[25] K. Martinelli. *Understanding Dyslexia*. Oct. 2023. URL: https://childmind.org/article/understanding-dyslexia/ (cit. on pp. 8–10).

[26] Nationwide Children's Hospital. *Auditory Processing Disorder (APD)*. Accessed: 2024-11-04. 2023. URL: https://www.nationwidechildrens.org/conditions/auditory-processing-disorder (cit. on pp. 23, 24).

[27] N. I. of Neurological Disorders and Stroke. *Learning Disabilities*. https://www.ninds.nih.gov/health-information/disorders/learning-disabilities. Accessed: 2024-11-04 (cit. on p. 6).

[28] J. Nisbet. *Game-Based Learning: Pros, Cons & Implementation Tips for Educators*. July 2023. URL: https://www.prodigygame.com/main-en/blog/game-based-learning/ (cit. on p. 6).

[29] NumberShire. *NumberShire*. 2023. URL: https://www.numbershire.com/ (cit. on p. 28).

[30] A. of PMC article. "Neuropsychological Perspectives on Dyscalculia". In: (2024). URL: https://pmc.ncbi.nlm.nih.gov/articles/PMC6440373/ (cit. on pp. 14, 15).

[31] M. Ronimus, K. Eklund, L. Pesu, and H. Lyytinen. "Supporting struggling readers with digital game-based learning". In: *Educational Technology Research and Development* 67 (2019), pp. 639–663 (cit. on p. 29).

[32] Scientific Learning Corporation. *Fast ForWord*. Language and literacy development software. 2024. URL: https://www.scilearn.com/fast-forword/ (cit. on p. 28).

[33] G. Speech. *Your Guide to Child Language Disorders*. 2024. URL: https://www.greatspeech.com/your-guide-to-child-language-disorders/ (cit. on pp. 11, 12).

[34] Speechify. *Visual Perceptual and Visual Motor Deficit Tools*. Accessed: 2024-11-04. 2023. URL: https://speechify.com/blog/visual-perceptual-visual-motor-deficit-tools/?landing_url=https://speechify.com/blog/visual-perceptual-visual-motor-deficit-tools/ (cit. on pp. 26, 27).

[35] M. C. Staff. *Dyslexia*. Aug. 2022. URL: https://www.mayoclinic.org/diseases-conditions/dyslexia/symptoms-causes/syc-20353552 (cit. on p. 8).

[36] T. U. Team. *Dyscalculia Fact Sheet*. 2024. URL: https://www.understood.org/en/articles/dyscalculia-fact-sheet (cit. on pp. 14, 15).

[37] T. U. Team. *What are Nonverbal Learning Disabilities?* 2024. URL: https://www.understood.org/en/articles/understanding-nonverbal-learning-disabilities (cit. on pp. 17, 18).

[38] U. Technologies. *MonoBehaviour*. Dec. 2023. URL: https://docs.unity3d.com/ScriptReference/MonoBehaviour.html (cit. on p. 44).

[39] U. Technologies. *ScriptableObject*. Dec. 2023. URL: https://docs.unity3d.com/Manual/EventFunctions.html (cit. on pp. 44, 49).

[40] U. Technologies. *Event Functions*. July 2024. URL: https://docs.unity3d.com/ScriptReference/MonoBehaviour.html (cit. on p. 44).

[41] Understood. *Classroom Accommodations for Dysgraphia*. Accessed: 2024-11-04. 2023. URL: https://www.understood.org/en/articles/at-a-glance-classroom-accommodations-for-dysgraphia (cit. on pp. 21, 22).

[42] Unity Technologies. *Unity*. Cross-platform game engine for 2D and 3D games. 2024. URL: https://unity.com/ (cit. on p. 43).

[43] V. University. *Language Processing Disorder*. Accessed: 2024-11-04. 2024. URL: https://my.vanderbilt.edu/speds2430/2020-topics/language-processing-disorder/ (cit. on pp. 11, 12).

[44] U. of Washington DO-IT Center. *Learning Disabilities*. https://www.washington.edu/doit/learning-disabilities. Accessed: 2024-11-04 (cit. on p. 6).

[45] WebMD. *Auditory Processing Disorder (APD) Overview*. Accessed: 2024-11-04. 2023. URL: https://www.webmd.com/brain/auditory-processing-disorder (cit. on p. 24).

[46] YoYo Games. *GameMaker*. Cross-platform game engine for creating 2D games. 2024. URL: https://www.yoyogames.com/ (cit. on p. 43).

[47] S. Zauderer. *33 Dyslexia Statistics & Facts: How Many People Have Dyslexia?* June 2023. URL: https://www.crossrivertherapy.com/research/dyslexia-statistics (cit. on p. 8).

[48] M. Zechner and contributors. *LibGDX*. Java game development framework for 2D and 3D games. 2024. URL: https://libgdx.com/ (cit. on p. 43).

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