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"Mistérios do Som" – development of a serious game for children with speech and hearing disorders

Dissertação – Mestrado Integrado em Engenharia Eletrotécnica e de Computadores

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UNIVERSIDADE NOVA DE LISBOA

Setembro, 2018

***"Mistérios do Som"* – Development of a serious game for children with speech and hearing disorders**

To my Family and Friends

Acknowledgements

I would like to thank my dissertation advisor, Tiago Cardoso, for guiding me through this work's development process and allowing me to take part in such an interesting, complex and rewarding world that is the serious games topic. Social Tech Booster and all its projects can truly give a different perspective of our society and open our eyes to the ones that need help the most.

For making this work and project possible, I would also like to thank the speech therapist Mafalda Caeiro S. Ruivo of *Colégio de Santa Maria*, for all her guidance and professional insight about the speech therapy subject and its challenges.

I would like to thank *Faculdade de Ciências e Tecnologia – Universidade Nova de Lisboa* for all the knowledge, experience and opportunities it gave me throughout the years.

Finally, my family and friends were essential for the successful path I took while on this stage of my life, and so I would like to thank them for their support, care and attention in good or bad times.

Abstract

The way we speak is extremely important when communicating with others, and out of all the forms of communication, this is surely the one that reveals most of our personality and emotions. Therefore, there is a problem to be solved when children begin to reveal some difficulties pronouncing and saying certain sounds and words, making it important to solve them promptly, as these problems can later reveal themselves in other topics, such as writing.

Nowadays there are several types of exercises and tools that aim at diagnosing, treating and accompanying children to overcome these problems. Although the exercises used in the therapy sessions are somewhat successful, it is difficult to captivate and incentive children during each session.

To mitigate these issues, serious games arise, a concept that unites education and entertainment into one. Serious games can improve results in therapy sessions, stimulating children and the therapist through a differentiating experience, and helping parents when their child is at home. It is within this concept that the "*Mistérios do Som"* game emerges, a serious game for children aged 6 to 10 that have speech and hearing disorders, combining gameplay in a 3D world with exercises that suit the needs of the child, giving the appropriate feedback according to their performance.

Keywords: videogame, serious games, speech therapy, mobile gaming, game engine, 3D modelling, Unreal Engine.

Resumo

A forma como falamos é extremamente importante ao comunicar com os outros, e de todas as formas de comunicação, esta é seguramente aquela que revela mais da nossa personalidade e emoções. Existe, portanto, um problema a resolver quando crianças começam a revelar algumas dificuldades a pronunciar e dizer certos sons e palavras, sendo importante resolvê-lo prontamente, já que estes problemas podem depois se revelar futuramente noutras áreas, como por exemplo a escrita.

Existem hoje em dia diversos tipos de exercícios e ferramentas que têm como objectivo diagnosticar, ajudar e acompanhar crianças a ultrapassar estes problemas. Embora os exercícios utilizados nas sessões de terapia sejam algo bem-sucedidos, é difícil cativar e incentivar as crianças no decorrer de cada sessão.

Como forma de mitigar estes problemas, surgem os jogos sérios, conceito que une a educação e o entretenimento num só. Os jogos sérios permitem que se obtenham melhores resultados nas sessões de terapia, estimulando as crianças e o terapeuta através de uma experiência diferenciadora, e ajudando os pais quando o filho está em casa. É dentro deste conceito que surge o jogo "Mistérios do som", um jogo sério para crianças dos 6 aos 10 anos com problemas na fala ou audição, aliando jogabilidade num mundo 3D a exercícios adequados às necessidades da criança e dando o feedback apropriado tendo em conta a sua performance.

Palavras-chave: Videojogos, jogos sérios, terapia da fala, jogos móveis, motores de jogo, modelação 3D, Unreal Engine.

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List of abbreviations

2D	Two-dimensional
3D	Three-dimensional
API	Application Programming Interface
APTF	Portuguese speech therapist's association
CPLOL	Committee of E.U. Speech and language Therapist and Logopedist
FCT-UNL	Faculdade de Ciências e Tecnologia – Universidade Nova de Lisboa
IOS	iPhone Operating System
KCR	Knowledge of Correct Response
OS	Operating System
RICS	Robotics and Industrial Complex Systems
SLCN	Speech, Language and Communication need
SLT	Speech and Language therapist
STB	Social Tech Booster
UE4	Unreal Engine 4
UI	User Interface
VFX	Visual Effects

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1

Introduction

The way we listen and speak with each other is important when communicating throughout our lives. Even with it being an essential part of our development as individuals, it is estimated that around 12% to 13% of primary and secondary school children suffer from some kind of Speech, Language and Communication Need (SLCN)[1]. These can be an entirely different language problem on their own, but sometimes there are some other health issues causing it. Those health problems can be a development disorder, a genetic syndrome, hearing loss or even brain damage [2]. Knowing that this problem exists does not help on its own and dedicated specialists need to deal with it.

Speech therapists are the ones in charge of solving this issue, and according to the Portuguese speech therapists association (APTF)[3], they intervene in areas such as:

- Communication
- Spoken language
- Written language
- Sound articulation
- Fluency
- Voice

Having such a broad area of expertise poses a challenge when speech therapists try to help people suffering from this problem. A disorder like this one affects many different

subjects and these specialists must act on all of them, either them being health or learning related, playing a pivotal role in the children's development, especially in the first school years when they are learning how to read and write.

> *"Persistent SLCN has been linked to reading difficulties, problems with literacy, educational underachievement, and behavioural difficulties."[1]*

When speech and language disorders end up being a long term situation due to late diagnostic , they can compromise the well-being of the child, either it being of academic, psychological or of social domain [4]. This can negatively influence academic performance at an early stage and consequently create psychological and social pressure within the child's environment.

This problem is even more serious when according to the Committee of E.U. Speech and language Therapist and Logopedist (CPLOL), two out of three countries in the E.U. leave the task of evaluating the patients up solely to the knowledge of each speech therapist, the United Kingdom being the only one with any standardization in this area. Several European countries neglect this kind of therapies, having an unbalanced ratio of speech and language therapists (SLTs) per person. One of those cases is Portugal, a country where there are over 10000 inhabitants per therapist (see Figure 1.1).

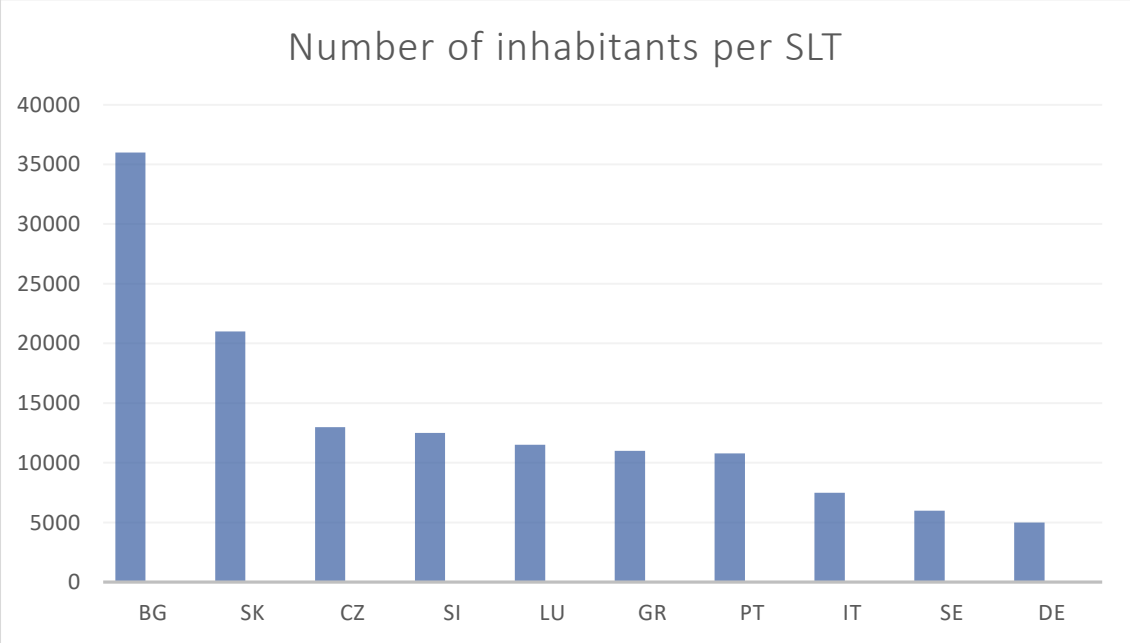

Figure 1.1 – Number of inhabitants per SLT, source CPLOL [5].

Ultimately this leads to children at any learning stage of their life, ending up not being properly diagnosed and treated, exponentially increasing the problem for future generations.

However, some children end up being properly diagnosed. In these small number of cases, adequate and dynamic coordination between school, parents and the therapist is a key part in overcoming the issue [1]. This support can greatly improve the success ratio of the treatments and exercises, customizing the approach and dealing with each individual issue personally.

1.1 Motivation

The problems that come from having any of the previously mentioned SLCN, create other issues that can negatively impact a child's life. Even if not adequately diagnosed and treated, some children in Portugal have access to a speech therapist that can evaluate and treat their condition accordingly.

For this work, a partnership with the speech therapist Mafalda Caeiro S. Ruivo of *Colégio de Santa Maria* in Lisbon was established. This private catholic school provides privileged academic bases for their students, focusing on a customized learning path that suits the needs of each child and never neglects their personal interests, social background, cognitive structure and development speed.

This institution provides adequate guidance when there is any suspicion of a SLCN, and a speech therapist identifies it early on, even at a pre-school stage, increasing the potential of success with the treatment and following the necessary steps for an organized caring cycle between parents, teachers and therapist, a key factor when treating these children.

When a speech disorder is diagnosed, the therapist schedules regular therapy sessions with the child. In these therapy sessions, the child must solve several speech and language exercises which are generally paper based and require constant guidance from the therapist. Most of the times these represent an undesired task, only adding unnecessary pressure to perform. The main challenge is to captivate these children with an appealing educational and diagnostic tool that can help them but still end up being a fun experience.

With the percentage of children using mobile devices as their entertainment source increasing [6], there is an opportunity in using these platforms as both entertainment and knowledge/therapeutic devices. Incorporating these devices in regular therapy sessions, will most likely improve the children's engagement in treatment routines both in school and at home with their parents and be useful in diagnostic situations.

1.2 Goals

In a search to captivate children during speech therapy sessions, this work's main goal is to create a game that can aid speech therapists and parents in helping children overcoming speech disorders. This tool should not focus solely on the exercises already used by the therapist (paper-based word banks) but also immerse the children in a fun experience that can somehow disrupt the usual tasks and exercises they are given. The ability to use this tool either during a session or at home is important, increasing the time it's used by the child and its overall effectiveness in treating the SLCN. Helping the treatment process is not the only benefit this game should provide, it should also be able to serve as a diagnostic tool, targeting a specific language disorder that the parents were not previously aware of.

Developing this game is going to require the study of topics such as videogames and serious games, but also the context of the respective demographic. This will ensure that children between the age of 6 and 10 will have a tool tailored to their needs and taste.

It's important to note that all the SLCNs knowledge required to develop this tool would necessarily need to come from a specialist of that field of expertise. This insight will come from the speech therapist Mafalda Caeiro S. Ruivo from *Colégio de Santa Maria* in Lisbon. This speech therapist's opinion and know-how is going to be key when developing the interface, mechanics, gameplay and exercises. The tool should also have a user profile system capable of saving relevant information about the child's performance and overall usage of the game. This will ensure that the therapist is able to access that information later and won't need to manually record the session.

This game should be appealing and fun to play, helping children overcome the potentially social disrupting issues of a SLCN by playing an interesting game in way that the main character's progress is also their progress, creating an incentive for additional game sessions.

2

State of the Art

While analysing the main topic of this dissertation, some insight on several concepts and definitions is needed to completely understand the possible goals and challenges ahead when developing a video game. It is important to understand the concept of video games, serious games and game-based learning, as well as a detailed research about the game developing methods, engines and tools available in the market today.

2.1 Videogames, what are they?

The importance of defining videogames ties into the reason why they are so relevant nowadays. Their popularity in recent years has catapulted the videogame industry to never seen numbers in terms of investment and economic growth. This industry, with more than three decades of history, is deeply rooted in our own culture, and now more than ever, videogames should be taken seriously and studied thoroughly as a great example of human-computer interaction [7].

The definition of videogame can be narrowed down accordingly to some concepts listed below:

- **Game**: a videogame is a game nevertheless, meaning it follows the same base concept as traditional games. It is fictional, making the player follow a specific set of rules, all revolving around a limited time and space. This means that a videogame does not need to be tied to a specific game genre, as it can be any kind of game if it is played using an electronic device.

- **Play**: the way you play a game is the key aspect that can and should grasp a player to the game they are playing. All the activities given to the user should be influenced by their actions and decisions, allowing certain freedom inside the game itself. The gameplay, challenges and objectives within it, must give a sense of accomplishment to the player, all accompanied by an adequate narrative that grasps the user to the experience.

- **Audio-visual apparatus**: challenges and the narrative presented to the player are extremely important to the experience itself but allowing the player to experience a certain level of immersion is largely due to the electronic system where the game is played. The interaction between the player and the game is one point that should not be neglected, as it can create interface issues that can block certain games from their target audience. This is one of the key differences when comparing videogames to traditional games, as they can be played in multiple and diverse platforms, such as arcades, consoles, computers, mobile phones, etc.

- **Story**: part of what engages the audience with several art forms such as film or literature, is the story. Videogames are no exception to this norm, but this is one topic they can certainly ignore in games like Pong (1972) or Tetris (1984). The gameplay aspect of a videogame, allows it to sometimes move pass the story part of the experience, as creating an interesting gameplay framework and mechanic ends up coming first in a game designer's development plan nevertheless. A videogame can have a story though, meaning that they can be narrowed down to a form of simulation, not only of a narrative but also of a gameplay system for a game concept.

2.2 Videogame structure and development

Now that the concepts that define a videogame have been summarized, the game development process and its context in our case should be addressed.

Videogame development has been dependant on the target device's capabilities and the development tools used. Building a three-dimensional game involves not only programming but also the creation of 3D meshes and their respective animations, which are generally made using 3D modelling software that was not created with the videogame

industry in mind, meaning that it was not suited to real-time animation [8]. Gradually, and as the videogame industry grew, these software tools have adapted to its goals and building the game world, scripting events and animating its different elements has gradually been made more accessible.

2.2.1 Three-dimensional game structure

The videogame structure of a three-dimensional single-player videogame, like "*Mistérios do Som"*, is illustrated in Figure 2.1. There are several tools that the player cannot access: geometry and animation exporters, world construction and layout, scripted event creation and physically-based audio/animation arrangement. These are the tools used by a developer when creating the game and are the focus when developing it. Using them allows them to create 3D models and their animations, define a layout for the game world (placement for models and interactions), code the events and logic of the game itself, and manage the audio and animations according to the game's state, making it possible to trigger specific sounds, music and animations when needed.

In any videogame, either it being two or three-dimensional, there are several aspects in common. These are the in-game music and sound effects control (sound management), saving score and game progress as well as usage logs (file input and output), the game's logic and challenge as well as the character's animation (scripted events and gameplay code) and the collision detection involving the players and the different world objects. But three-dimensional games add a complexity layer that their two-dimensional counterparts lack, the graphical part. This requires additional processing power both graphically (rendering) and logically (collision and physics). 3D games are demanding and require more processing power to run, and so the rendering time and processes of their 3D models and what happens to them during gameplay must have the target device's capabilities in mind.

All these variables and their connections must be considered and adapted to the final product's goals.

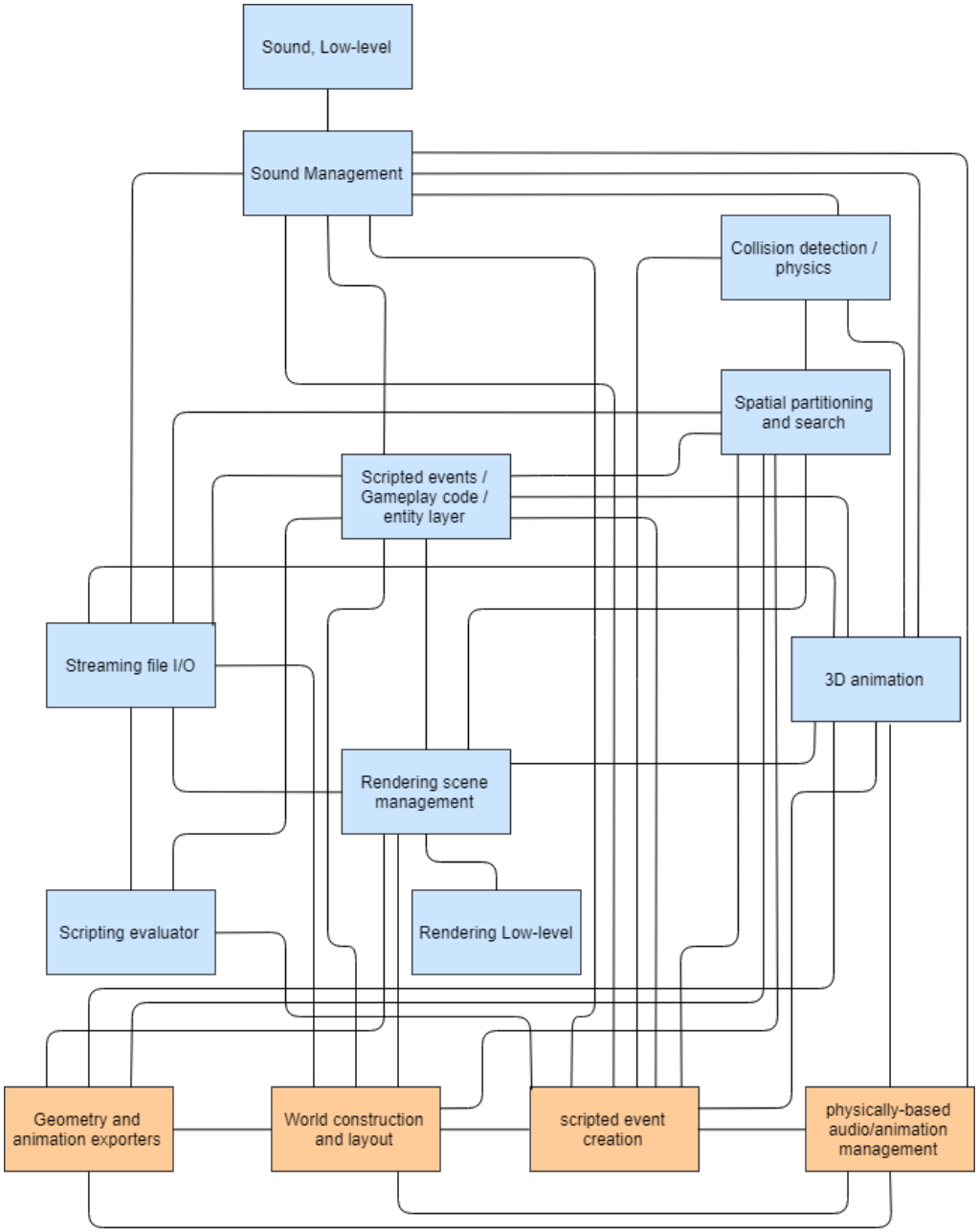

Figure 2.1 – 3D game structure [8].

2.2.2 Videogame development roles

Having established a videogame structure and defined its different aspects, the next step must be its design. A videogame development team oversees the game's creation and implements the game mechanics and elements that are part of it. According to the game design worksheets (attached and filed according to this work) provided by Tiago Cardoso in the subject of Digital Games Technologies [9], the different roles in these teams can be divided 4 positions and their respective tasks:

- **User Interface Designer:** Should define de control input scheme (Joystick, mouse, keyboard, touch screen, gyroscope) adapting to the different situations

- **Level Designer:** In constant and fluid communication with both the lead designer and the user interface designer. Defines the level logic and its challenge.

- **Art Designer:** Should define all the concept art for the game (menu, character, world map) and follow a consistent design philosophy that suits both the target audience and the game's plot.

- **Lead Designer:** Manages the workload, assigning and monitoring the different tasks. Should assume the final decisions and the direction the development progresses should take, constantly making sure the elements communicate properly and keep the game simple.

It is important to note game development teams vary in size and do not necessarily need to have at least 1 person for each role. When developing a videogame, the mind-set of the ones developing it should be focused on splitting the tasks in these different categories and assign them accordingly.

2.3 Serious Games and game-based learning

2.3.1 Videogames vs serious games

Now that we know the things that define a videogame and its development, it is important to understand another branch of this industry that often ends up forgotten by the public and major videogame development companies, serious games. These games are first and foremost videogames, but the thing that makes them special and stand out from the crowd is that they, on the contrary to the mainstream types of games, have an objective apart from the main gameplay itself.

The objective in a videogame is the main source of entertainment and it is represented by the "play" part explained earlier in this chapter. This aspect, part of what is called the challenge and gameplay, is seen as the explicit objective, present in every videogame. But serious games are different, as this is not their only objective. With these kind of games (see Figure 2.2), there is an implicit objective aimed at improving a certain skill or ability [10]. However, this objective should not dominate the game's development and supress the explicit one and all the other aspects. Balancing and articulating them should create a more effective and efficient final product that adequately meets the requirements.

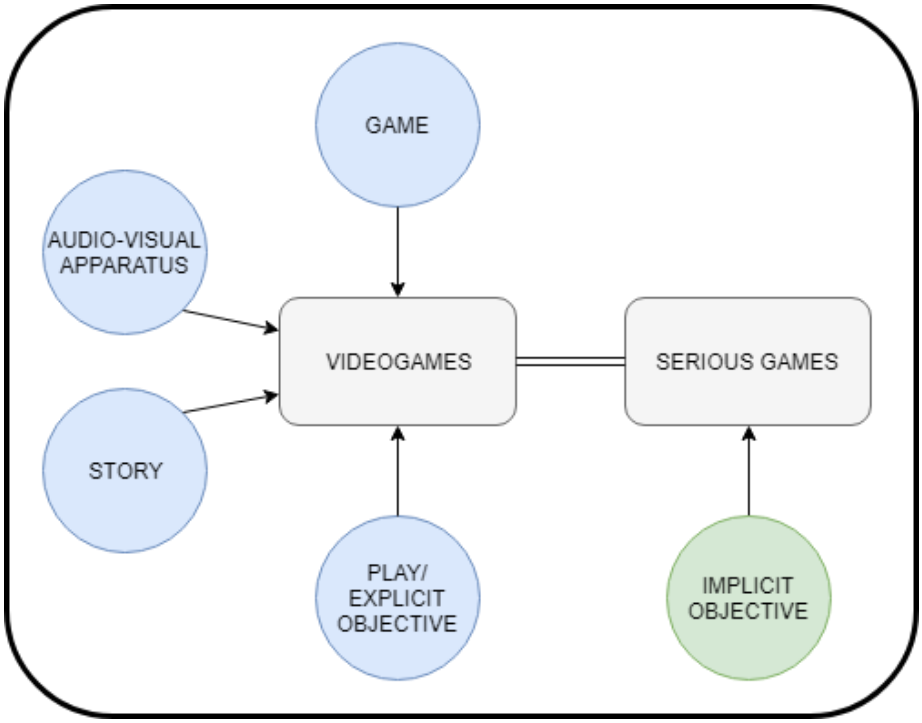

Figure 2.2 – Serious game in a videogame context.

2.3.2 Potentials of game-based learning

The implicit objective is the key part in every serious game, but it is important to understand how the player improves a skill or ability when playing the game. To improve that while playing the game, the player must ultimately train or learn something. This game-based learning must be somehow relevant when compared to traditional forms of education. It should not eliminate them, but use its specific traits, appealing to different audiences (videogame players) and using the technological advantages at their disposal (electronic devices).

Children are playing more videogames in their spare time and the pursuit for educational games has been growing at steady pace in the past few years [6]. The chance of using them as a way of teaching young people cannot be ignored, but before we decide that game-based learning is the right way to go, we need to assess the real benefits in motivation and teaching abilities that videogames bring to the table.

According to a study on how the instructions and feedback affects motivation and learning effectiveness [14], two types of game instructions, learning and entertainment ones, were compared in two experiments. The study shows that learning instruction are more effective because the mind-set of the player is focused on a learning experience instead of an entertaining one. The most interesting result of these tests was that if the player receives positive feedback because of their successful performance, the results are extremely positive on a deep learning level. In other words, if we truly want to take advantage of game-based learning, providing the appropriate knowledge of correct response (KCR) to the player is essential. These results show that the KCR can also manage the fear of failure, which is important when developing games for children with special needs, that are many times in a difficult social position. Feeling that the game acknowledges their positive performance by giving some sort of positive feedback, will play an important role when developing the gameplay mechanics and the overall experience.

Tied to adequate feedback mechanics when the player answers an exercise, a well-built reward system is recommended to encourage children to play longer sessions and increase overall enjoyment when playing the game [15]. These rewards can be an extra stage with only the fun part in mind or even an organized score table depicting their performance and game usage.

2.3.3 Serious game's development plan

Every videogame project needs to follow a development plan that suits its needs. The three-dimensional videogame structure analysed earlier and the different roles/tasks in a game development team must be considered right from the start and during development. Serious games are special games, as they need a development team comprised not only of designers and programmers but also specialists that can provide the necessary know-how to improve a skill or ability.

The development plan can be divided in 5 different stages: planning, design, development, evaluation and deployment [11]. These stages are essential to the creation of successful and high-quality serious games (see Figure 2.3).

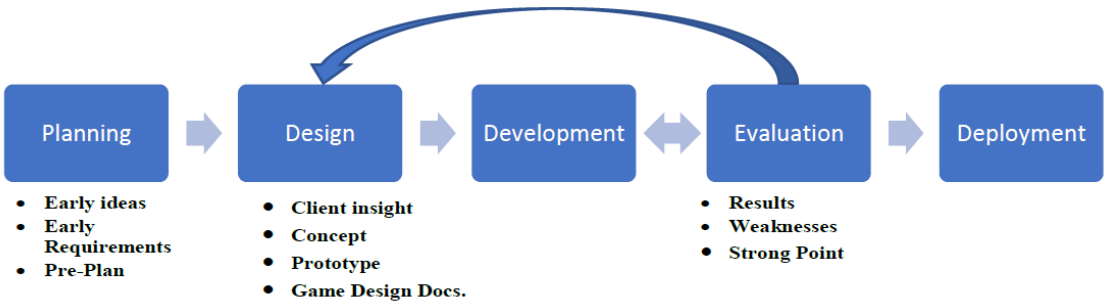

Figure 2.3 – Digital serious games development plan [11].

Starting with the planning stage, the initial ideas must be discussed and a schedule with the different tasks should be set. Moving on to the design stage, a concept is created according on the client's insight (specialist) and a prototype is developed. Apart from the specialist's insight at the initial game design stage, while being developed, the serious game should be evaluated and if need be, the development team should go back and correct some of its design flaws. These evaluations make sure that the final product is prepared for deployment.

The number of people needed to execute this plan may vary depending on the ambition of game being developed and its budget. However, with serious games, the implicit objective content provider (specialist) is the member that stands out from the usual team [10]. This role's main task is to define the challenges, instructions and their difficulty, as well as the proper feedback needed when playing the game. Its expertise is crucial when developing a serious game because the usual team of game designers, programmers and researchers do not have the required knowledge about the issue the game is trying to solve. This means that a constant and healthy back-and-forth of information and opinions between the specialist and the videogame development team is of utmost importance.

2.4 Game development tools

The development process of a videogame requires several software tools. We can divide those necessary to build a three-dimensional videogame in two categories: game engines and design software. These are an integral part of both the design and development stages and should be chosen according to the final product and its characteristics.

There is a wide variety of three-dimensional modelling software available. These allow the user to create similar 3D models but have different approaches in several aspects, most notably, the UI. The software described in table 2.1 must be free-to-use, and if not, there should be a free version for university students [12].

Table 2.1 – 3D modelling software overview.

Name	User level	Description
SketchUp	Advanced	Free 3D modelling software, available on Microsoft Windows and Mac OS. The basics are simple to learn, but the more complex tools can pose a difficult step while using them. SketchUp Warehouse provides many user uploaded 3D models that can help when defining a concept early on. Extensions are also available and extend this software's functionality for free.
Blender	Professional	Open-source software available on Microsoft Windows, Mac OS and Linux. It can be used for 3D modelling or even some more specialized task, making it a more professional choice. Apart from this, Blender can also be used for visual effects production and its Python API can adapt it to any project's needs. This large number of features, many not modelling focused, makes this software tool difficult to master.

Three-dimensional modelling software is used to create the game's models, but a different kind of software is used to develop the game and all its programming routines and scripts, the game engine.

"A game engine simplifies the task of the programmers by offering convenient abstractions for the hardware and operating systems on top of which the game runs." [13]

A game engine is thus a framework for game creators that allows for some abstraction between the gameplay scripts and the hardware running the game. These engines are mostly cross-platform, making it possible to develop a game suited to different devices and operating systems.

Two of the most popular game engines available today allow their users to develop games for free, making it possible to enter the videogames industry with relative ease [14]. Table 2.2 describes these engines individually.

Table 2.2 – Game engines in detail.

Name	Cost	Description
Unity3D [15]	Personal edition: Free. Professional edition: 125$/month.	The personal edition of this engine provides most of the features, but the more complete professional version is not free, which can pose a problem when developing more complex games. Some of the included features are: Real-time rendering engine, native graphics API, Unity Performance reporting, wide asset library (Unity Asset Store), native C++ performance (Unity-developed back-end IL2CPP scripting), 3D data optimization with PiXYZ [16]
Unreal Engine 4 [17]	Free to use, with 5% royalty after the first 3000$ revenue per game.	Complete game development engine, developed by Epic Games, with features such as: photoreal rendering in real time, full C++ source code included, Blueprints, VFX & particle system, extensive animation toolset, terrain and foliage, unreal audio engine, among others [18]. This 3D focused engine's official website also provides step-by-step tutorials, documentation and an active developer community.

Both game engines described in table 2.2 can be used to develop similar games. Unity3D is more mobile platforms and 2D oriented, used in fast and simple programming situations, as it is easier and relatively fast to test a concept [13]. The asset store is much more complete, and the gameplay/level scripting is far more accessible than most of its contesters.

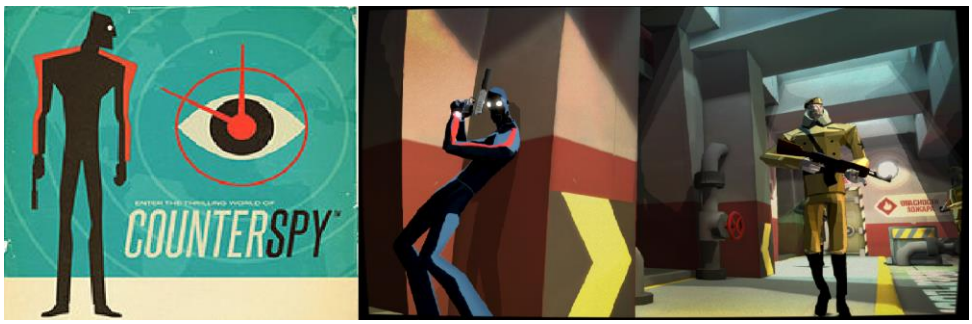

Figure 2.4 – Counterspy videogame artwork [19] , developed in Unity3D.

UE4 uses Disney's Physical Based Rendering, making it more accessible for game developers to render high quality light and shadows [20]. This game engine is known for the great visual fidelity and realism its games have, without compromising the overall performance of the final product. Even if it is initially free to use, Epic Games charges 5% of the total revenue generated by the game if it surpasses the 3000$ mark, which can be a serious problem for highly successful game development companies.

Figure 2.5 – Street Fight V videogame screenshot and logo, developed in UE4 [21].

2.5 Market study

When developing a new videogame or any kind of product, it is important to search for any previously released ones. This will make sure that there are not any other games that already fulfil this work's requirements. As it was previously stated, game-based learning has a lot of potential, and can help children if correctly implemented. The hearing and speech disorder problem has severe repercussions if not diagnosed and treated correctly. Present in several developed countries like the US, where close to 8 percent of children between the age of 3 and 17, have some kind of speech or hearing impairment [22]. The high percentage of mobile media devices in each and every household represents an opportunity to appeal the referred demography and better diagnose and treat these issues [23].

2.5.1 Speech and hearing serious games available

There are a lot of serious games that tackle a variety of different subjects. In a way to somehow narrow down the search for the ones available in the market today, the games encountered must target speech and hearing disorders. Apart from that filter, the games should be set in a 3D free-to-roam environment and preferably meant for mobile devices.

Another relevant search topic, perhaps the most relevant of them all, is the one that puts the speech and hearing issues into context, by searching serious games that help children with those problems and are available in the Portuguese language. "*Mistérios do Som"* should solve problems for Portuguese native speakers only, as the sound comparison exercises will have Portuguese words exclusively. After all the previously mentioned criteria were filled, the games found were listed in Table 2.1.

Table 2.3 – Serious games targeted at SLCNs.

Game Reference	Target Audience	Description	Game artwork
[24]	Children with language disorders.	Developed in Unity 3D, set in an interactive 3D environment. Several stages are spread throughout the game world.	
[22]	Children aged between 2 to 6 with speech and hearing problems.	Set in a 3D world with objects scattered around the map and the player can interact with them and solve the challenge triggered by them.	
[25]	Children with speech disorders.	A syllable practice game, that helps children with various word/sound exercises.	

2.5.2 Market analysis

The games illustrated in table 2.3 are already tackling several SLCNs, so they must be analysed properly, to develop a different and successful game. The first two games shown, share some visual and gameplay aspects, as they are both set in a 3D world and give allow the player to explore it in a somewhat free manner. Both are aimed at the PC/mobile platforms and developed in Unity3D.

The first one was used to prove the advantages of using a game set in a 3D world to solve speech and language problems. It has 25 interactive three-dimensional objects that the therapist can place around the map according to the children's needs and although the usage logs can be accessed after the play session, the therapist's guidance is important, comforting the children [24].

The second game is targeted at a younger audience (before the age of 6) and features simple voice commands for the character's movement but also when repeating the word that was just listened in an exercise. It works only with some words like numbers, months or seasons, which can limit its grasp in the diverse array of sounds that exist [22].

The last game, "*Palavras aos bocadinhos*", is the only one that helps treating SLCNs in Portuguese native speaker. The game is basically an array of exercises aimed at training syllable recognition with different words and images. There is not a plot or a 3D world for the player to explore, only exercises with a 2D perspective and a drag-and-drop methodology. It is aimed at mobile platforms and is currently available on IOS and Android [25].

2.6 Illations

Understanding the concept of what makes serious game a different branch of the videogame concept and understating the structure and design/development plans, is going to be very important when developing a prototype. Using the referred tools and considering some of the work developed in the speech therapy serious games topic to date is going to contribute to both a more efficient game and a different experience when compared to the others.

3

"Mistérios Do Som" – Speech therapy made fun

In this section, the aspects surrounding the design and plan of the tool developed, are going to be addressed, all accordingly to the recommendations and requirements discussed in partnership with the speech therapist Mafalda Caeiro S. Ruivo and her team. This will hopefully make *"Mistérios do Som"* a helpful tool in aiding speech therapists and parents at home or at school that must deal with children suffering from these sorts of problems.

3.1 Game requirements

To adequately set the necessary requirements for the final tool itself, several meetings with the speech therapist and her team needed to be arranged. This would allow for better understanding of the problems children with speech disorders face everyday and, more specifically, the challenges faced both by the therapist and the patient in ordinary speech therapy sessions in school.

The meetings should consist of a healthy back-and-forth between the therapist's needs, and the know-how and creativity when programming and designing the tool. The

first one set several goals that were to be met by the final prototype, and although they could change while developing the game due to either developing setbacks or the therapist's team opinion, these were the foundation for "*Mistérios do Som"*:

- **Mobile platform focused**: using this tool to aid in eliminating paper-based exercises in each session, means that mobile platforms such as smartphones and tablets should be the used to run the game. This will also allow portability and flexibility when the child plays the game, not limiting the usage place and time to the school and therapy session, as his or her parents can install the game in their own devices and play it at home. This focus should not restrict the existence of a PC version, as it should support that platform on Microsoft surface for example (Windows platform).

- **Fun**: one of the main focal points of this tool is to captivate children when solving speech therapy exercises. The game world should be as interesting, colourful and engaging as possible, suiting the age group it aims to help. In this aspect 3D worlds can engage the player in that kind of experience and are also an unexplored type of game in Portuguese speech therapy. Music will also play an important role, as it defines the mood for the experience, and as this speech therapy game focuses on listening to specific words, sound is key.

- **Usage log**: apart from the obvious fun of having exercises in a video game, one of the main advantages is the possibility of having a way to register the different children as separate users and consequently collect information from their game experience and the way their playing. This allows for the therapist and/or parent to know how well the child is doing while playing the game (which exercises are more often correct or incorrect), without having to be there.

- **Instinctive and simple controls**: dealing with complicated menus and exercise layouts can be frustrating sometimes. Children with these kinds of problems should be able to pick the game up and play, leaving the difficult side to the speech disorder exercise itself, so a simple and logical way of navigating the menu and game world is essential.

After considering all these basic principles, we should contextualize them. The game's main goal, as with any other serious game, is to combine an interesting and compelling gameplay (explicit objective) with several educational/health exercises (implicit objective), with the difference being that "*Mistérios do Som"* should have speech therapy exercises that improve and monitor the speech capabilities of children between the age of 6 to 10.

3.2 Design direction

Right from the start, some decisions must be made about the game's design direction allowing it to be developed accordingly. Bearing that in mind, the game design worksheets were filled.

Starting with the main design decisions and development guidelines, in the lead game designer worksheet, most of them were set. The main character is a robot that doesn't know how to speak, and the player must solve that problem. This robot is playable in a colourful world, with a third person top-down camera perspective, accompanied by synthesizer focused soundtrack. While controlling the character, the player must complete several stages which comprise of speech therapy exercises (sound comparison), with two possible answers that lead to either a positive or negative feedback screen. Simplifying gameplay is important for younger audiences and touch capable devices, and so the character's movement shouldn't be overly complicated.

Moving on to the level designer worksheet, there, each level can be independently described. The levels work basically the same way, with different stages scattered throughout the map and a few of them that must be completed, with the only two differences being the size and setting of the map. *Parque dos sons* (the biggest level) is set in a park with bushes, trees and picnic tables. *Casa Misteriosa* is set in a front yard of a pink house. This is the smallest of the three levels, with this area only sporting a pool and a small garden. The third map, *Praça da brincadeira*, is a plaza with a fountain and garden, surrounded by a street and several stores, each with some distinct architecture and colour.

Being mobile platform focused, the game must have a touch friendly interface. In the user interface designer worksheet touch controls are described by mirroring those of a standard mouse left-click. This way, the game could be played in both PC an smartphones/tablets and have the same look, as there is no need in having on-screen controls that would block the view of the game itself.

The last worksheet analysed is the art director's worksheet. The art direction of a game has the same importance as the previously analysed design choices. This defines the style and look of the game, keeping it coherent with the concept and appealing to the target audience. The game world will follow the low-poly concept in which a low number of polygons and vertices is privileged. The colour pallet used should be bright primary colours, avoiding the use of darker tones. The scene lighting and its use is also important, influencing shadows and time of day, but in this case the colours used in the textures should emit light themselves, improving graphical fidelity and brightness in the game. The character should be the most detailed asset in the game, because it is the player's focal point, and a more rounded and complex appearance should be chosen. Every art decision should be evaluated and tested in-game to assure acceptable frame rates and performance while playing.

Every worksheet filled accordingly, can be found annexed to this document.

3.3 The game in detail

Every single requirement and design decision described previously will be very important to reach a relevant and effective final product. It should be noted that the game should allow the therapist and the parent to control it by themselves, without the need of any admin aid (this scenario is in a late development stage, as the developer's insight and knowledge of the tool is essential for proper understanding of it in the beginning stages of prototype testing).

The tool is going to be described according to the way a user would face the different stages when playing the game, starting at the login system, followed by the menu, levels and usage logs.

3.3.1 Login system

A proper login system must assure that the three different user types, the player, the carer (therapist or parent) and the admin, can access the game. Each one of these users can access a different kind of information when logged in.

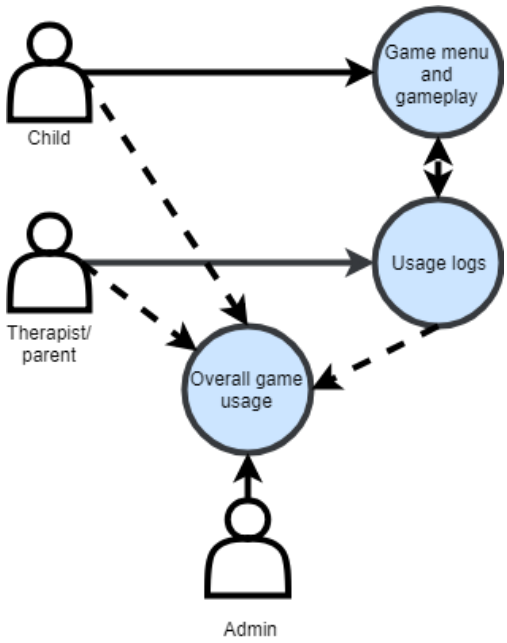

Figure 3.1 – Use cases and content accessed.

When the user starts the game, a login screen shows up. The information entered is going to inform the game about the user type it must deal with. As illustrated in Figure 3.1, there are three main aspects in the game: the game and respective menu, the child's usage logs and finally, the overall game usage.

After logging in, the child can only access the game menu and the game itself. While progressing inside the game, each exercise's response will be saved in a specific usage log, that monitors the child's performance. The therapist or parent caring for that child, have access to the child's usage logs inside the game, meaning they can assess their progress and performance while playing they play it. Every information entered by the child is going to be saved for further analysis and evaluation, contributing to the overall game usage log, a feature only accessed by the admin for statistical purposes only.

This system is responsible for the game's success as it improves and monitors the child's performance. Therapists can access the child's usage logs locally at any given time, allowing them to evaluate a specific language disorder and if there was any improvement, or not, with precision and accuracy when accessing them. The parents are

also important in this system, as they can allow their children to play the game and assess if there is any minor speech and language disorder they weren't aware of previously, leading to a possible future speech therapy session and more qualified evaluation of the issues.

3.3.2 Game Structure

Apart from the login system and the information available in each use case, the game must be structured in a way that allows for a logical and simple sequence of events. Much of this structure (see Figure 3.2) revolves around the menu and every on-screen option from start to finish. The menu should not pose an extra difficulty step and must provide seamless connection between what the user intents and the actual option chosen.

The log in screen is the first thing the user is faced with when launching the game. After entering the user name and an age number, either a new user profile and save state are created or a previous game session save state is loaded. No password is required in this step, as each save state is linked only to the name entered. This happens because of the age group being targeted in "*Mistérios do Som"*. Children aged 6 to 10 years old aren't used to passwords being used to login and adding this feature would create a problem in the future. As it is meant to be played locally, therapists must guide the children when logging in for the first time and find ways to bypass the problem when there are two or more children with the same name and age.

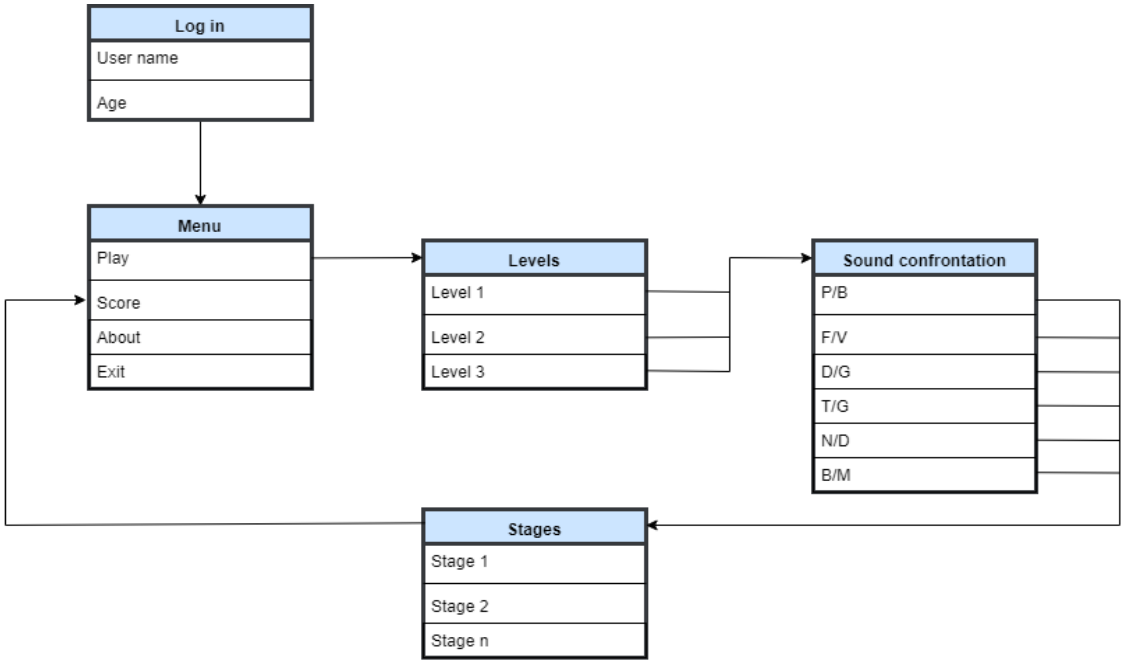

Figure 3.2 – Login, menu and stage structure.

Once logged in, the main menu shows up. This menu is the central part in the game and the user can choose one of four options: Play, Score, About or Exit. If score is chosen, the user performance is displayed, showing the number of both correct and incorrect answers. The about option, describes the game itself and its purpose, and the exit option closes the game. The play option however, is the first one is the obvious focal point of the menu, and when pressed, the level buttons pop up with the three different levels available.

The last step before the game play itself is the sound confrontation menu, in which the player must choose one of the six options available. If a speech disorder was already spotted previously by the therapist, the child must be guided to the exercise that can help them the most. On the other hand, if the game is being used to find a possible speech disorder, then the option chosen here is not relevant, as the game will cycle between confrontations.

Each stage completed adds information to the score in that specific confrontation, and it's going to be saved as each one is completed, meaning that if the player closes the game without finishing the level, their performance and progression in the specific stages are always there when logging in next time.

3.3.3 Stage and reward structure

Choosing the desired sound confrontation triggers a small explanation on how to play the game and its objective. After this explanation, the player is free to play the game and walk around the world. Several stages are spread around the map (coloured circles). There is no specific order in which the player must complete them, but each one of them follows a colour code:

- **Blue**: Player spawn, triggering a small audible tutorial on how to answer the type of exercises in this level.
- **White or yellow**: Normal stage, triggering an exercise at any given time when stepped on.
- **Red**: End of level, triggering final score screen.

As the user enters a stage there are three possible outcomes (see Figure 3.3). If the user answered correctly in 13 previous stages, the level ends and a new confrontation is suggested. If only 7 stages were answered correctly, a mini-game shows up, rewarding the player halfway through the level. Finally, if none of the previous checks were met, the sound confrontation exercise appears, and the answer is saved in the save game state.

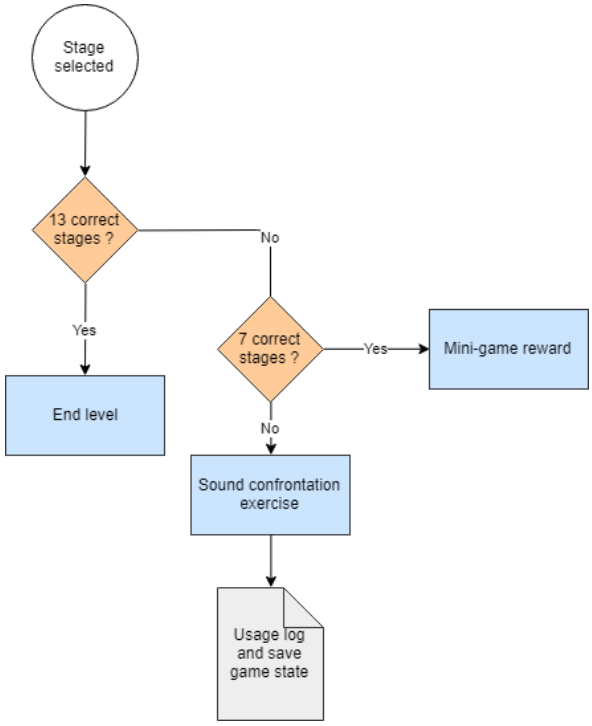

Figure 3.3 – Stage select possible outcomes.

Focusing on the sound confrontation exercise (see Figure 3.4), there is an expected chain of events when the user starts. There are three buttons available, the listen button plays a word sound file belonging to the sound confrontation group that was previously chosen and starts a timer, hidden from the player so he or she feel no time pressure while answering. By pressing this button, another pair of buttons are made available, allowing the player to choose between two letter sounds and answer the exercise. When the choice is made, depending on the answer being correct or incorrect, the user receives positive or negative feedback (KCR) and the choice is saved in the save game state allowing for in-game progression and further data analysis, including the time it took to answer.

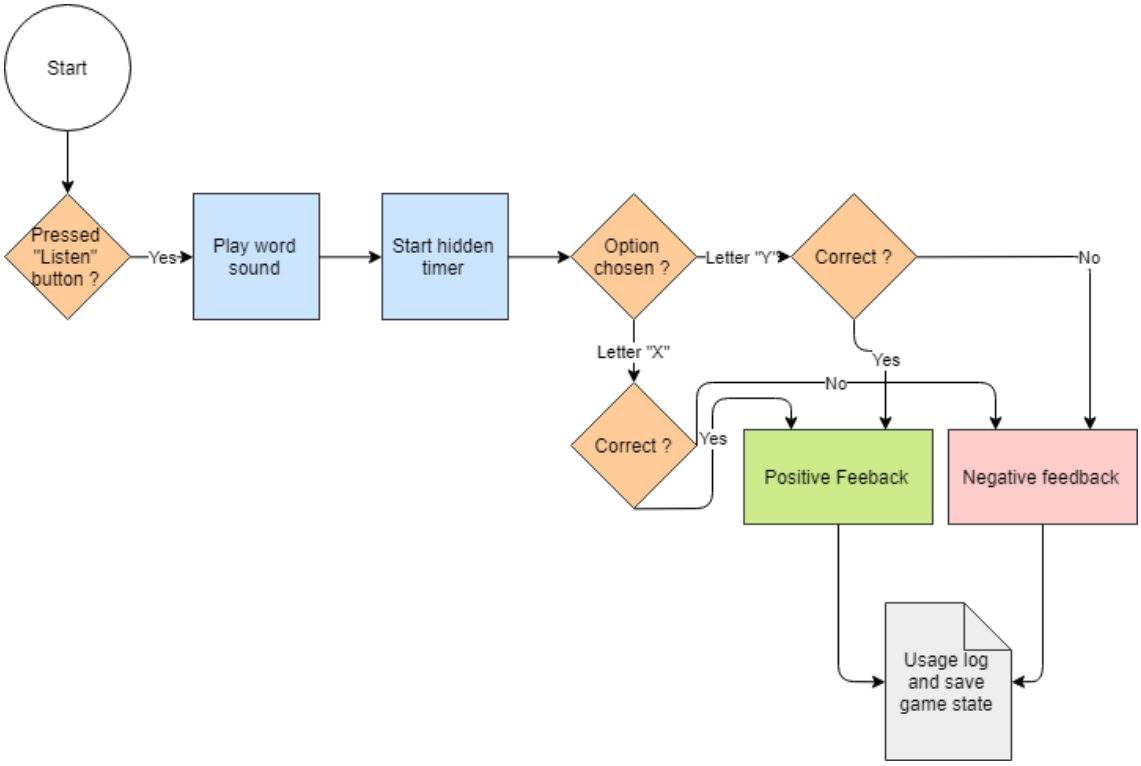

Figure 3.4 – Exercise answer sequence and feedback.

3.4 Next steps

The design elements discussed in this chapter are what hopefully make this game an effective tool. A proper login system and game sequence/structure must be implemented adequately, allowing for the usage logs of the children playing the game to be accessed by their carer, either them being a parent or a therapist.

By using the tools available and the speech therapy know-how provided by the speech therapist, the game developed is going to be detailed in the next section.

4

Validation

Having properly structured the game's logic and foundations that will make this tool adequate for helping children with speech and language issues and their therapists, in this section, the developed prototype will be addressed. It is important to analyse its design, challenges and overall success when applying the concepts previously chosen for the different stages of the game, either them being gameplay or data analysis within it.

4.1 Software tools

4.1.1 Three-dimensional modelling

The early design stage was important to define development goals and discuss ideas when meeting with the therapist. To do so, several three-dimensional models were needed to explain the gameplay and design choices in the game world, and the software chosen to develop them was Google SketchUp. This choice was made mainly because of its interface controls and the fact that this software was previously used in some other subjects, which allowed for fast prototype design.

By using this 3D modelling tool, it is possible to create a model of buildings, interiors, landscapes and more. In this game, there are 3 colourful maps: A park, a house and a city square. All the different maps have buildings, trees and even a bridge, which contributed the decision of choosing this software. The user interface can also be totally customized to suit the user's needs.

As illustrated in Figure 4.1, the model takes a central position in the screen, followed by the toolbar on top (every function needed to move, resize or draw the model), and the default tray on the left (entity info, materials, components, styles, shadows, instructor and soften edges options).

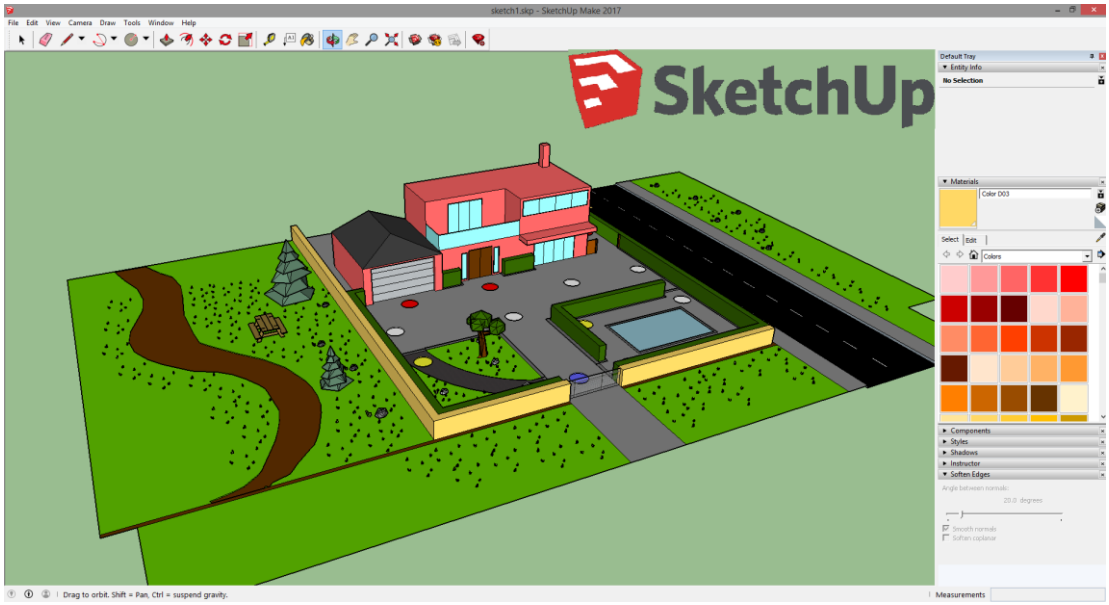

Figure 4.1 – Google SketchUp layout and level model.

Using the drag-and-drop approach, the model seen in Figure 4.1 was easy to create and colour, and by using the free assets available on Google SketchUp's own service, SketchUp Warehouse, several assets such as the trees and bench were placed in the world.

4.1.2 Game engine and programming

Three-dimensional modelling is relevant when developing a three-dimensional videogame, but the integral part of it all is the game engine. The game engine acts as the framework that allows for programming gameplay scripts, different scenes, models, sounds and even storage of several information in the device the game is played.

It is also important to note that nowadays most game engines are free and available in most computer operating systems, making it difficult to chose one just from price or

platform availability alone. So, when choosing the game engine game engine that best suited the development of "*Mistérios do Som"*, several aspects were considered:

- **Free to use**: eliminating the initial barrier of buying a game engine and thus accelerating and making the development of this solution possible.
- **Cross-platform**: allowing the game to be played in different devices and operating systems such as Android, IOS and Windows.
- **Wide documentation and tutorials**: helping when developing the game and learning on how to use the game engine.
- **3D oriented**: Being focused on three-dimensional gaming makes development possible and avoids performance issues in the final solution.

After some initial thoughts on this matter, the game engine chosen was Unreal Engine 4. This game engine met all the requirements mentioned and it was also previously used in another subject, making the most obvious choice.

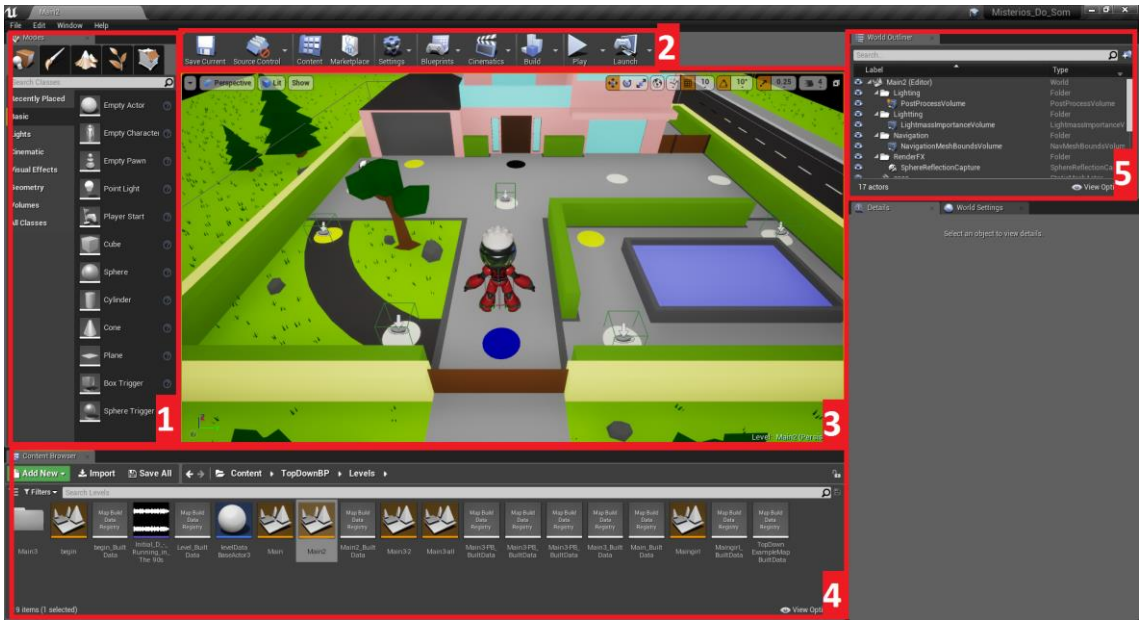

Figure 4.2 – UE4 layout.

As illustrated in Figure 4.2, UE4's usage layout can be divided in 5 different areas:

1. Section with a drag-and-drop approach to place actors (in-engine assets) in a scene such as basic forms, light sources, cinematic effects, visual effects and change geometry and volume, as well as painting, landscaping and add foliage.

2. Toolbar with functionalities such as saving progress, changing the current level blueprint and cinematics, play the current level and launching to level in another platform connected to the computer.
3. Level game world and straightforward interaction with its actors, enabling the user to place, delete or move them (rotating or shifting using three axis)
4. Content browser containing models, materials (colours and textures), sounds, blueprints. This section uses a drag-and-drop approach as well.
5. World outliner organizing every actor placed in the scene, allowing the user to sort, enable or disable them precisely.

Blueprints are an integral part of what makes unreal engine so distinct from other game engines. They can be used in low code situations, allowing for fast and trouble-free concept tests and even complex algorithms. These can range from level to character control blueprints (see Figure 4.3) and use functions available in the game engine's library and others created by the user to program a certain game behaviour either it being the movement of a character or the background algorithms when saving or loading a game file.

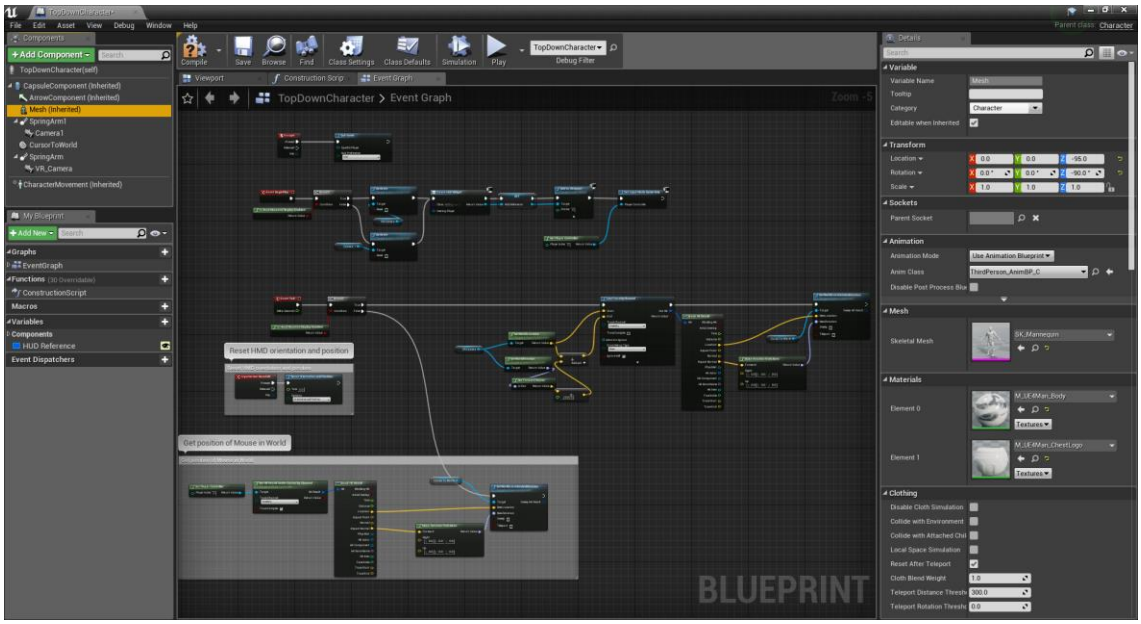

Figure 4.3 – Character movement blueprints.

4.2 The game

The functionalities, processes and models of the game will now be explained step-by-step, starting with the user login and menu, the different levels and finally, the different stages encountered throughout the game.

4.2.1 Login and Menu

Logging in is very important as it defines the user type starting the game (see figure 4.4). The login screen only shows up once, when the game opens, and the user is prompted to enter its name and age.

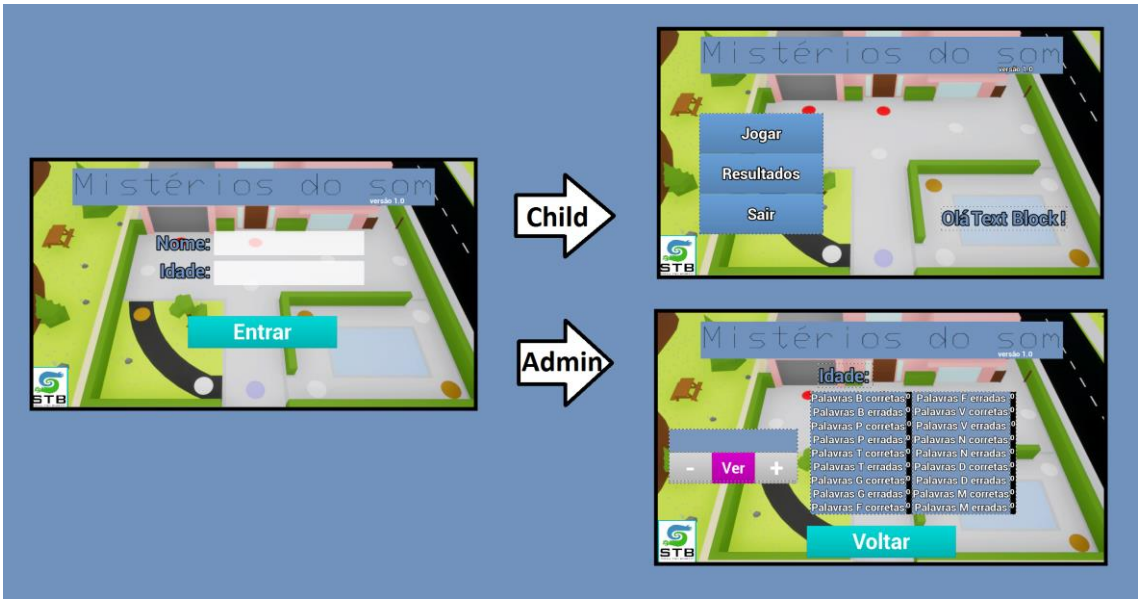

Figure 4.4 – Login and menu screens.

The Enter button (*Entrar*) only works properly if the user entered both parameters. The name field is important to distinguish the users and it serves a greater purpose than a simple and often random username, as it creates the possibility for a more personal game experience and it allows for children to never forget their name in the game. Age is also relevant in this game context, as it can help when analysing data later, allowing for a specific age group study.

Different use cases were also implemented in this area. By entering a name, age and pressing Enter, a user profile is either created from scratch or a previous one is loaded, except when the "dev" name is entered. In this case, instead of the main menu being shown, a screen showing the user performance appears, allowing the therapist to scroll

through the different patients and their scores, accessing their name, age and the number of correct and incorrect answers given for each letter sound in previous gaming sessions.

Going back to when a normal user logs in, the main menu is shown. There, the user is greeted with an on-screen message, customized with its name. There are also three buttons available to press: Play (*Jogar*), Score (*Resultados*) and Exit (*Sair*). When "Play" is pressed, a pop-up window appears, showing the three levels available. If instead, "Score" is pressed, an alternative window shows up with the usage log. This is almost identical to the page shown when an admin logs in, with the difference that it only shows the score for that user. The last button available is Exit, and when it is chosen, the app is simply closed. Every single one of these pages and menus have the same background image, depicting an overview of the house level, and the colour scheme in both the buttons and the game title banner is coherent.

One other feature of the above-mentioned login and menu areas is the background music. A looping track composed from scratch that differentiates the game, linking the gaming experience with the song, reiterating the focus on sound (hence sound comparison) and making the game more unique. This song and every other sound heard throughout the game where composed, recorded and produced using the software tool Ableton Live 9 and a private sound studio.

It is also worth noting that the Social Tech Booster logo on the lower left corner, leads to the respective website when clicked. Social Tech Booster, or simply STB, is an initiative within the RICS research and development group of FCT-UNL. Its aim is to boost the use of technology (mainly videogames) in social and health related causes. This game is also part of that initiative and it would make sense that people playing the game could also know more about the work developed here.

4.2.2 Game levels

The menu area allows the user to choose one level to play the game on. There are three different levels, with different sizes and settings, allowing for new and refreshing experiences whenever they are played.

After selecting the level, the user must choose the sound comparison inside the level (see Figure 4.5). This screen allows the child to play whatever exercises they want to if

they are left unguided (suitable for speech and language issues diagnostic), or the therapist can guide them and indicate the most adequate choice considering the patient's case.

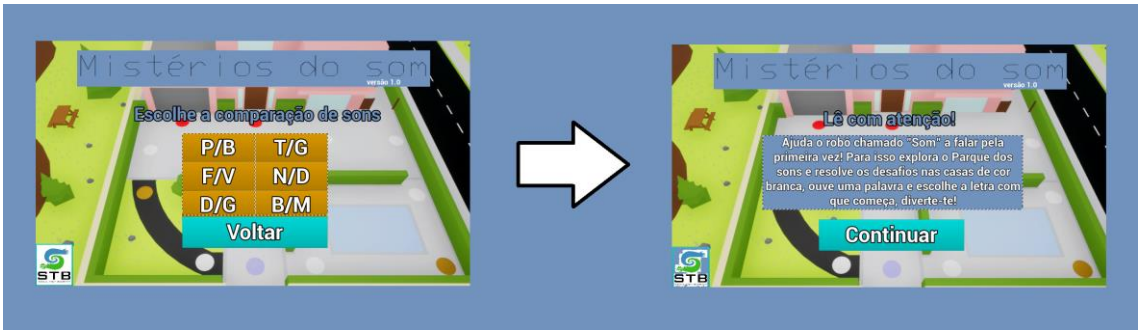

Figure 4.5 – Sound comparison menu and tutorial screen.

When the choice is made, the instructions on how to play the game appear. This is a crucial part, as it instructs the child on how to play the game and gives some detail on the plot surrounding the character and the objective of the game. It is important that the evaluation during the gameplay is not too obvious to the child. Serious games should help children with their problems and issues, but they should be fun as well. If a child plays the game to have fun, the therapy session will be much more effective as there is less pressure when answering the exercises and the game itself will be used as an escape to the normal therapy session format. This is not in any way replacing it, but it should improve its effectiveness and appeal.

Turning the focus on the levels again, as previously stated, there are three available:

- ***Parque dos sons*** ("Sounds park" – lower section of figure 4.6): The biggest map of them all, with 23 different stages. This park has several bushes that make for a maze-like appearance and some pine trees, rocks and wooden picnic tables. Even with all these elements, the main focus is the big lake, bridge and sailboat. The user is free to walk everywhere right from the start, even over the bridge.
- ***Casa Misteriosa*** ("Mysterious house" – Upper left corner of figure 4.6): A front yard of a pink coloured modern house. This level was the first one developed, and so it ended up being the most importance when proving the concept. The level is the smallest with only 10 stages but even a pool and a small garden the player can explore.

- ***Praça da brincadeira*** (“Play plaza” – Upper right corner of figure 4.6): A city plaza with a big fountain at the centre. The player can walk in the garden and walk to the music (piano rooftop), gaming (controller rooftop) and food (pizza rooftop) stores. This level has 12 stages.

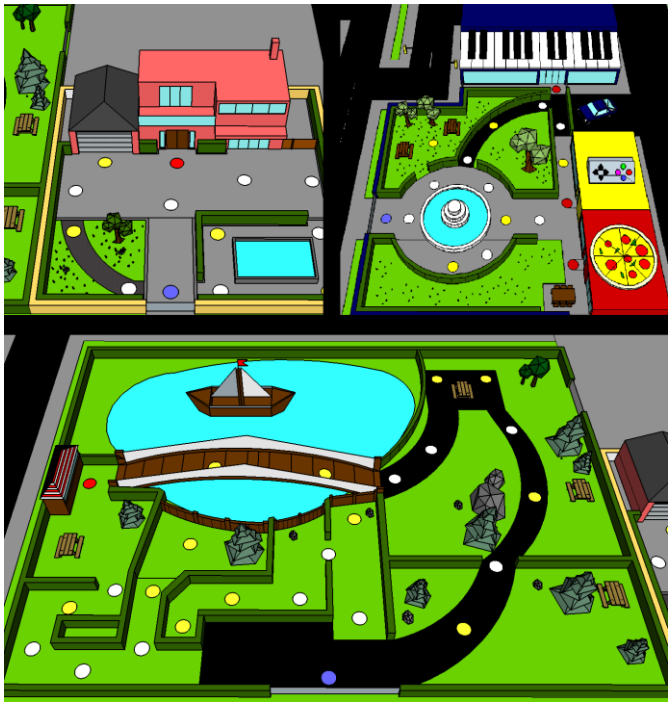

Figure 4.6 – *Mistérios do Som’s* three maps.

Every level map and model were developed using Google SketchUp. These were then exported to AutoCAD Maya, for file compatibility reasons, and only then exported to Unreal engine 4. The colour pallet present (materials and textures created with the game engine) is coherent in all of them and the modelling style is based on the Low-poly idea. Model design may not seem, at first, a focal point in an efficient game and may appear as a simple cosmetic decision. But with “*Mistérios do Som”*, the target platforms were mainly Android and IOS devices, in many cases with limited processing capabilities and power consumption problems as software gets more and more demanding. The Low-poly design allows for better graphical processing and improved frame rate when playing the game, all because of the smaller number of vertices it needs to process.

In Three-dimensional games, vertices processed are not only visually relevant. The character is going to walk all over the map and it is possible, and likely, that it touches the trees and other elements scattered in it. In unreal engine 4 and other game engines, it is possible to implement or generate a collision scheme for the model. This function limits the area in which the character can walk, making it impossible for it to pass through the

floor, walls and other objects. The low-poly models help this process, as the number of vertices in each model is much smaller than it would be in a more realistic looking one.

4.2.3 Character

The player's focus when entering the level is going to be the character. It is important that the child playing builds some degree of empathy with it, as that is one of the things other three-dimensional story driven videogames focus on.

In "*Mistérios do Som"*, *Som* is the main character (see Figure 3.7), a robot with no mouth and that does not know how to speak. The player is asked to help the robot in solving the different speech exercises. The robot model is the only element in the game that does not follow the Low-poly design, much because it needed and deserved a lot more detail.

Figure 3.7 – Game's main character.

The robot has a male and a female version, but the only one available in-game is the male, due to performance issues with the female version (due to the model's complexity).

Moving or animating three-dimensional characters is not straightforward, as it needs to feel fluid and believable, especially in a detailed character model such as this one. Unreal engine separates this in three different areas: Mesh, Physics and Skeleton (see Figure 4.8). Starting with the skeleton, this represents the model in different joints and bones, allowing for better control over the body and in this game engine a free humanoid skeleton is available. Some simple animations like walking, running, jumping and punching are also available, making it easier for newcomers to implement their game. This skeleton must be assigned to a mesh and physics, allowing it to control that model, our robot in this case.

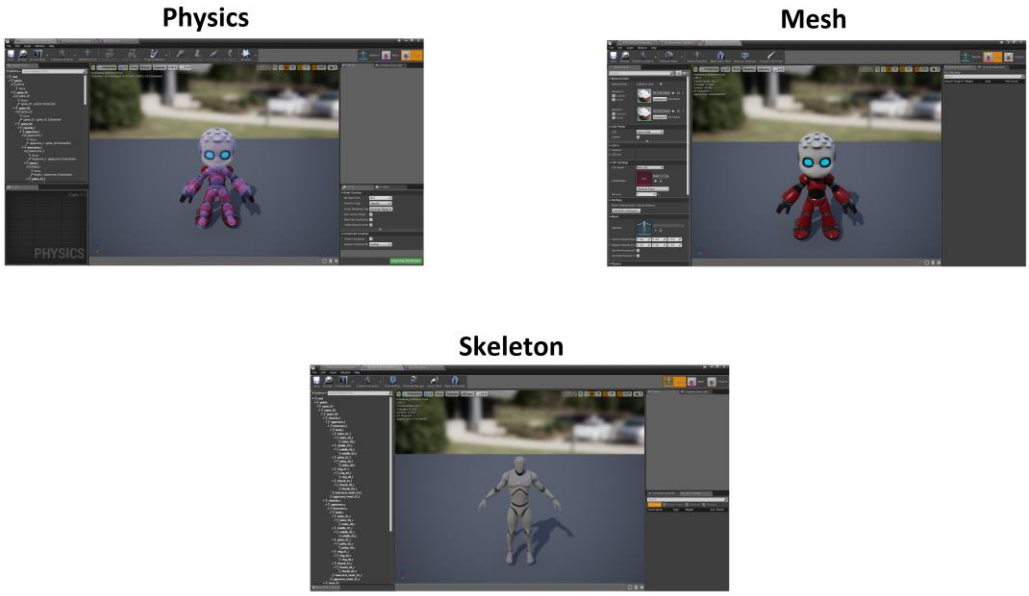

Figure 4.8 – Physics, Mesh and Skeleton UE4 menu layout.

4.2.4 Gameplay

There are 2 different gameplay modes in each level. A top down third person mode in which the player controls the character and a two-dimensional stage with the sound comparison exercise.

As the level starts, the character spawns at the blue circle in the map and the player can move it everywhere. This is where the user interface and controls come into place. "*Mistérios do Som"* is a multiplatform game, meaning that it cannot only have touch or keyboard controls, and it is targeted at relatively young children familiarized with mobile devices but not hardware keyboards specifically. Having simple controls is key to break

the barrier between user and device, and so, a similar control scheme was implemented for all devices.

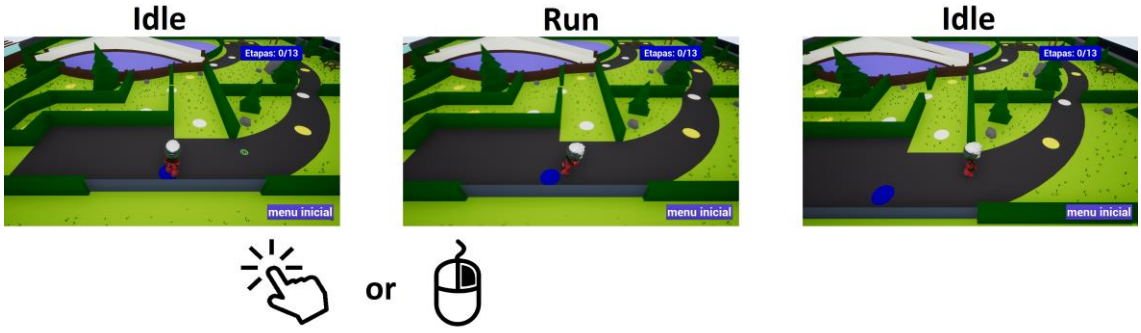

Figure 4.9 – Touch and mouse input results.

As illustrated in Figure 4.9, the character starts with an idle animation. If played in a PC, a green circle highlights the mouse cursor and its location. When the user touches the screen or left-clicks the desired location, the characters starts a running animation and travels to that spot taking the fastest route and stopping when it reaches the destination. By controlling the character and its movement like this, there is no need of adding extra on-screen buttons that would steal screen real-estate.

Moving on to the way the game is played, the main idea is that of a three-dimensional interactive board game. The map has several stages around it that the player can interact with by stepping on them (see Figure 4.10). This action triggers a sound comparison exercise and stops the character in place until the player completes or exits the exercise.

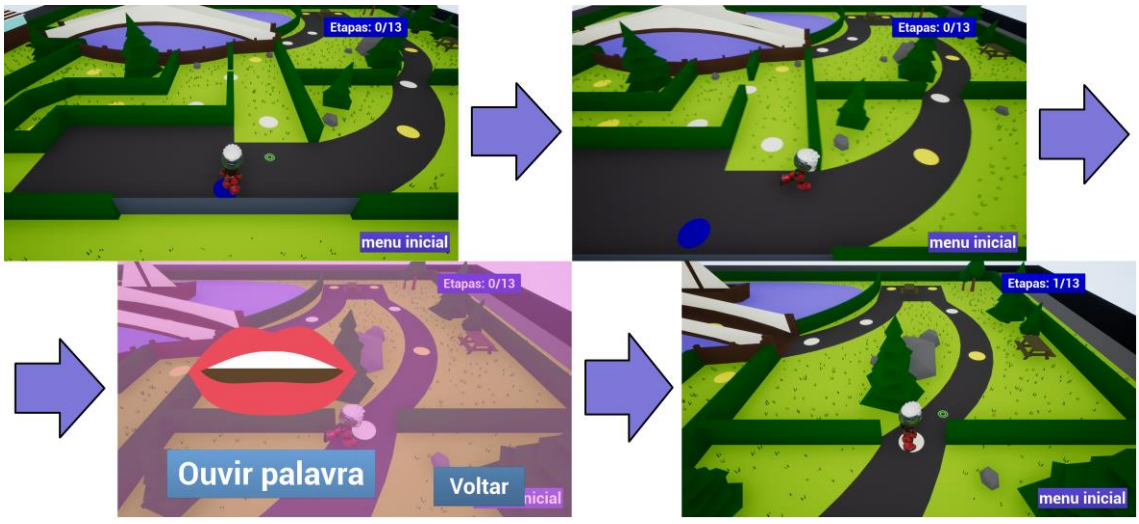

Figure 4.10 – Level Gameplay sequence.

The stage tints the screen with a transparent colour, allowing the user to see where the character is. There are two buttons available at first, with which the user can either listen to the word and start the exercise (button *Ouvir palavra*) or leave and go back to the map (button *Voltar*). The answer options are only made available if the user chooses to listen the word first, avoiding a possible exploit in answering randomly.

The word for each stage is never displayed on screen and can be heard as many times as player wants to. Depending on the player's sound comparison choice, when the exercise is triggered, a sound file from that specific comparison is picked at random. This means that it is not possible for the child to memorize that a word is in a stage, as it would eliminate the difficulty and effectiveness of this serious game.

Knowledge of correct response is very important when aiding children and others playing a game that's supposed to improve a certain skill. When the user chooses one of two answers possible, a screen depicting a positive or negative result shows up (see Figure 4.11) and their respective sound feedback. It is also worth noting that in situations in which the child has severe speech or language issues, excessive negative feedback can discourage children when playing it, and so, the therapist must guide the children through the experience and help them solving the exercises.

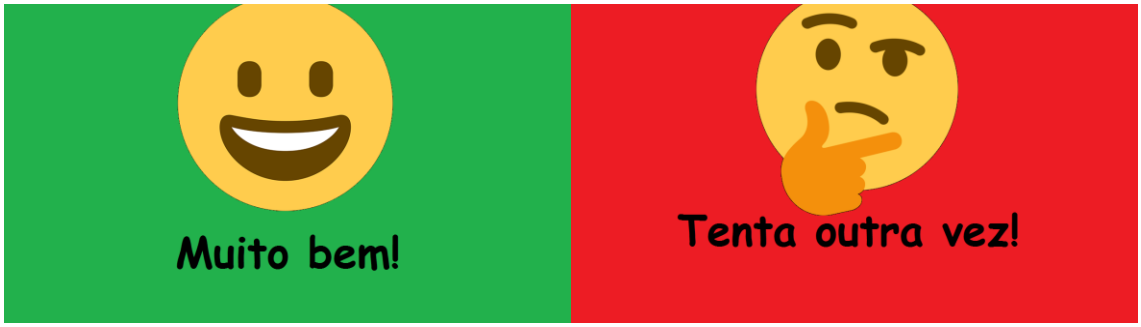

Figure 4.11 – Positive and negative feedback.

After that, the game returns to its top down view of the character and the correct stage counter on the top right corner of the screen increments, constantly giving the user some information on their progression.

4.3 Data collection

4.3.1 Game usage logs

Collecting relevant data and adding it to the usage log of the child is one of the key features in this serious game. This is going to greatly help the therapist with the patient aiding process and truly differ from other types of exercises such as paper-based ones. The child can use the game autonomously and the therapist can access their score and progress later. The data collection sequence is illustrated in Figure 4.12.

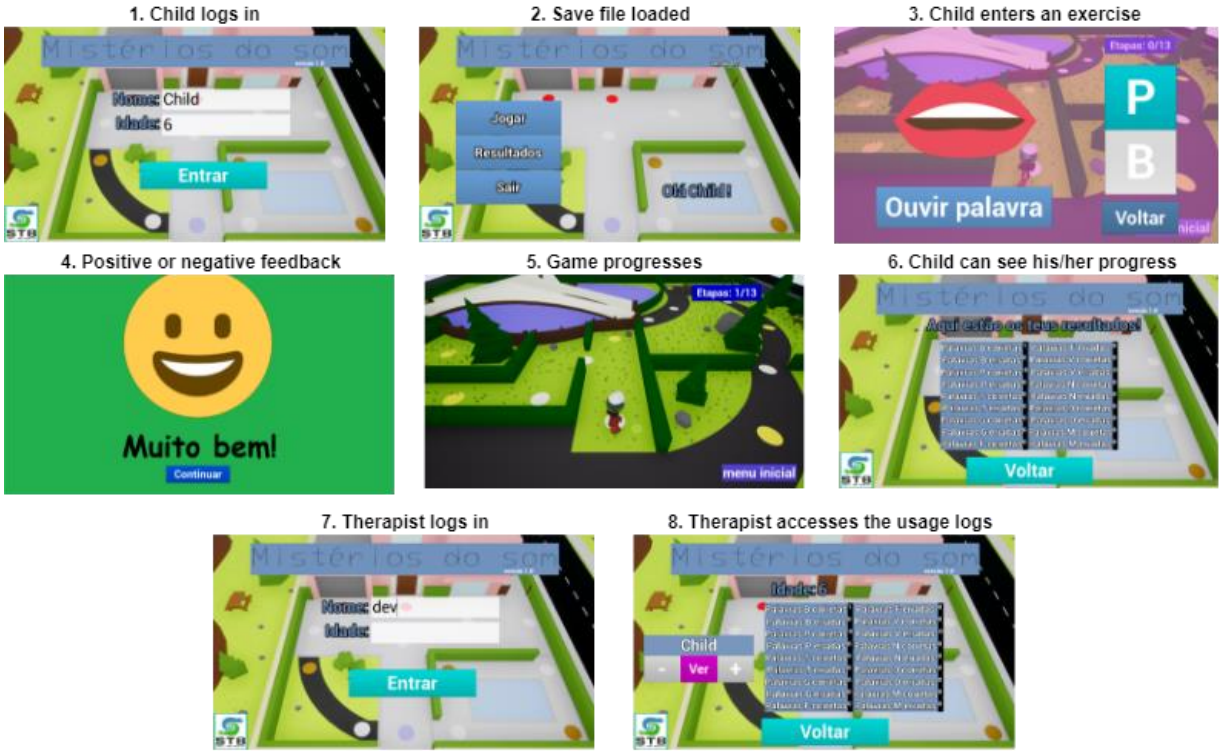

Figure 4.12 – Game usage logs and how they are accessed.

The child logs in and a save file is created and loaded, or simply loaded if there was a save file already store with those credentials. From then on, the user is logged in and can only access its profile and score. After choosing the sound comparison and the level to play on, the child can enter an exercise in the game map, as shown in Figure 4.12 (3.) the sound comparison is P/B. When the answer is given, the correct or incorrect choice is saved in the usage log permanently, a screen shows the proper feedback and the number of correct answers for that level is added by 1. The overall score can then be accessed by the child in the main menu and by the therapist by logging in with the word “dev”. This special login name allows the therapist to see other scores if another of his patients also played the game, analysing the progress user by user.

4.3.2 Inquiry

Apart from the previous mentioned data collection method, an additional inquiry was created. This inquiry is aimed at children aged 6 to 10 years old and it should be answered by the child after playing the game. One of the main advantages of this method is that it is suitable to both children with speech and language issues or not, making it easy to both analyse the child's problems and the game's appeal in the target demographic.

A copy of the inquiry can be found in the annex section of this document.

4.4 Validation results and data analysis

The game was developed alongside the speech therapist Mafalda Caeiro S. Ruivo and her team right from the start, meaning that every decision during the game's development was made by discussing it in several meetings at Colégio de Santa Maria (following a development plan). The idea of this tool came from the therapist and the STB group, using the specialist's know-how of the speech and language issues and the electrical and computer engineering knowledge, making it essential to reach common ground on the game's matters.

According to the initial plan, a meeting took place in September 2017, only with the therapist Mafalda Caeiro S. Ruivo, in which several aspects were covered:

- Level design
- Map concept
- Target Platforms

After this, a barebones version of the game was developed during the next 5 months. This version, based on the initial concept and the topics discussed in the first meeting, had a fully functional menu and the three different levels. The main character was not implemented yet, but the model was already finished.

The next meeting took place in February 2018 and it involved the therapist Mafalda Caeiro S. Ruivo and her team. In this meeting, the latest prototype was presented as well as the main character model. The therapists were very happy with the improvements made to the initial concept and approved the prototype developed.

Field testing was the next step, and to make it possible, a word bank was needed for each sound comparison. These words play a pivotal role in making the game effective in aiding children with speech and language issues, meaning they could only be provided by the therapists. This content took some time to be elaborated, delaying the word recording sessions and ultimately, the estimated development deadline.

The first complete PC prototype (version 1.0) was finished by the beginning of June 2018, which made it difficult to test it with the therapist's patients at *Colégio de Santa Maria*, as the school year was ending. Nevertheless, a game testing day took part in the 7th ClubeMath session on June 2nd, 2018, courtesy of the assistant Professor Maria de Fátima Rodrigues of the FCT Mathematics Department.

During this session, "*Mistérios do Som"* was playable in 2 PCs, inside one of the designated activity rooms. Children aged 7 to 10 years old (our sample) were the only ones allowed to play the game and they were monitored and helped if needed be. They were asked to wear the available headphones (better acoustics and noise-cancelling capabilities) and control the game only by using the mouse connected to the device. As the children played the game, their respective usage log was created, and at the end of each play session they were asked to answer a copy of the previously mentioned inquiry.

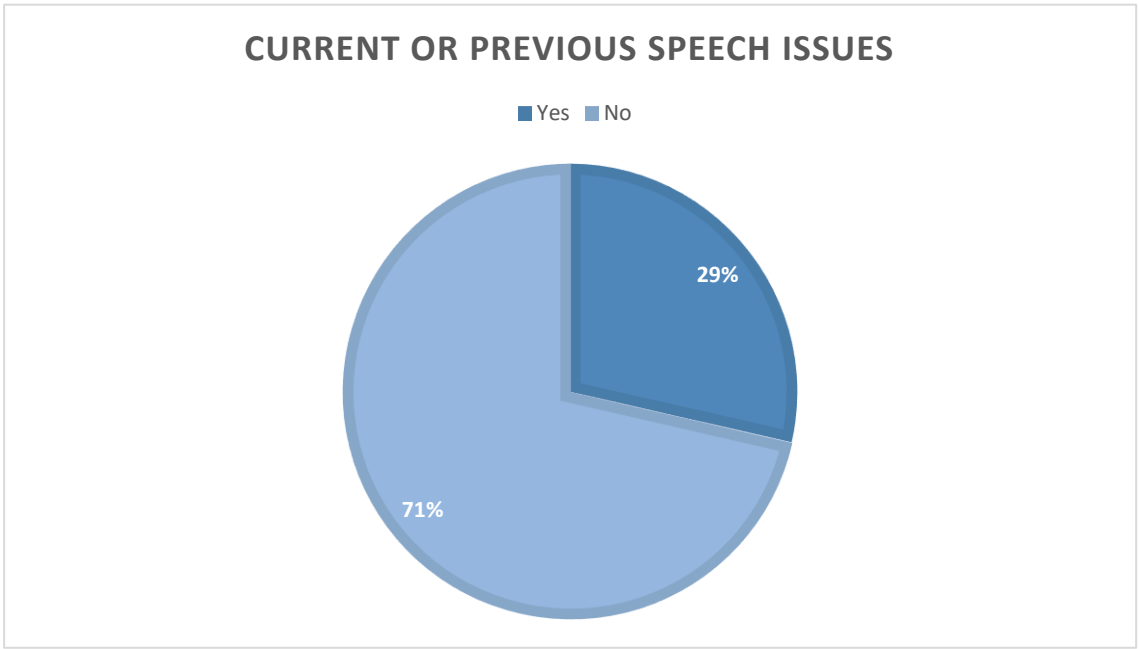

Figure 4.13 – SLCN incidence out of the children inquired.

The first topic analysed will be the speech and language issues incidence in the age group inquired. The data shows that roughly 30% of the children suffer or have suffered

speech and language disorders of some kind. These kinds of disorders may disrupt their ability to learn and keep up with other children in school, proving that a tool able to provide speech and language issue diagnostic can be useful in identifying these cases early on. Another important information is the fact that out of the children that never had any speech issues, 71% say they know someone that suffers from it, improving the chance of reaching more and more children suffering from these problems. Even if most children playing were not dealing with a speech and language issue, some had problems solving the in-game exercises, signalling the most difficult sound comparisons as being P/B, D/G, N/D and F/V respectively. Similar sounds can be sometimes misunderstood but it only reinforces the fact that these sound comparison exercises can be useful in distinguishing them. These difficulties were not acknowledged by the children, as all of them said the game was not hard at all. This may be due to the KCR system implemented, a system that focuses on the positive feedback and progress in the game.

One other aspect of this game is the entertainment. Focusing on the Edutainment (Education + Entertainment) concept, the game should balance the educational part mentioned previously and still be entertaining.

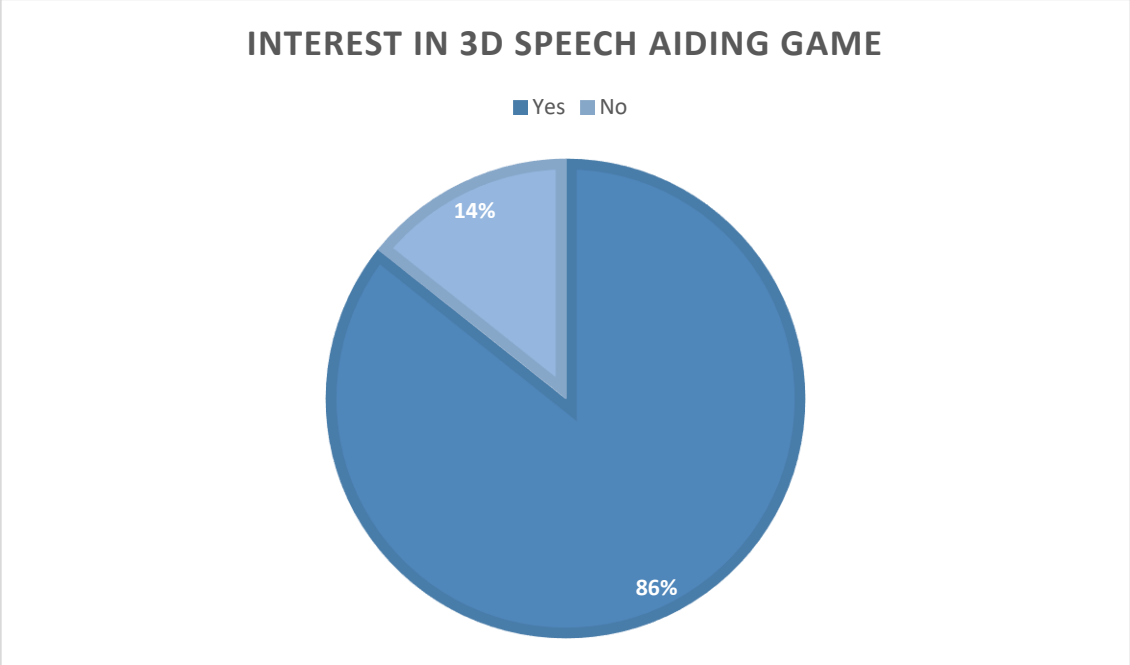

Figure 4.14 – Interest in 3D Speech aiding game.

Most children showed interest in playing a three-dimensional game that helped them with complicated words. The game gathered a lot of kids around the PCs because of its visuals, map and main character. Visual appeal can be subjective, but the colour pallet chosen and the game running at 60 fps and no problem occurred during the different game sessions.

5

Conclusion and future work

Speech therapy and the SLCNs it tries to solve is an intricate and complex subject. The therapists that solve those issues are sometimes faced with a wide array of problems that can have a negative effect in the children's early learning stages and ultimately, impact their development and social life. The lack of consensus and standardization in what defines a SLCN can lead to deficient diagnosis and different approaches when treating them.

Cases in which children are already being followed by a speech therapist pose a particularly distinct challenge, motivation. Speech therapy sessions are generally focused on specific exercises that tackle the issues depending on the patient's needs but can sometimes be monotonous and seen as an uninteresting task, as repeating words and sounds are mostly their main strategy.

Taking advantage of the mobile devices available nowadays and their increased popularity among children, could solve the motivational issue that therapists face a lot of times. A tool that could use the improved graphical processing abilities and portability of such devices, as well as monitor and evaluate the children's SLCN progress would help solving those problems and possibly improve the patient's perception of the regular therapy session.

Researching some topics around this concept alongside the speech therapy insight provided by Mafalda Caeiro S. Ruivo, were the foundation for "*Mistérios do Som*", a tool that harnesses the abilities of devices such as mobile phones, tablets and PC, helping therapists, parents and children diagnose and overcome SLCNs, in the form of a serious game. This multiplatform game runs with both touch and mouse controls featuring a

straightforward interface. A login system allows for different use cases, saving the patient's information (name and age) and allowing the therapist or parent to access the progress and performance. It can be used as simple diagnosis tool, identifying a possible SLCN, or as a therapy session add-on, motivating the children with a colourful and interesting experience while solving sound comparison exercises.

The validation results proved that the tool was indeed successful in targeting speech disorders, even if the children were not aware of them. Identifying the specific number of times that a child answered correctly or incorrectly in a sound comparison exercise, will help the therapist in upcoming speech therapy session, choosing the most adequate sound comparison exercises that suit the child's need.

The inquiry was helpful to evaluate the children's overall enjoyment when playing the game. Being an effective tool was not only down to the educational side of the game, it also needed to be a fun experience. The 3D game world, its colours and sounds, the main character and setting contributed to the overall appeal of the game. Achieving an entertaining experience that could help children overcome the problems that come with a SLCN was the main goal of this tool.

Developing a digital serious game and following the plan's different stages proved more complex than initially though. The back-and-forth of information with the therapist was not always the best and the meetings schedule to assess the game's progress was conditioned by the normal time constraints of the profession. Future serious games that follow the digital serious game's development plan should set a fix schedule of meetings between the developer and specialist that can assure a healthy and proficient partnership.

Future work on this tool should focus on increasing the number of words recorded, and consequently offering a wider array of sound comparisons. SLCNs are related to a multitude of sounds, not limited to the ones featured in this work. This bigger library was not added due to app size constraints, mainly due to the 3D world and its resolution, graphical fidelity and sound quality.

One other aspect should be the speech recognition functionality. The game allows children to distinguish similar sounds and in turn helping them pronounce them correctly. But evaluating their speech abilities and the way they pronounce the different sounds would heighten the possibilities of this tool to a different level. Speech recognition tools are already available but adapting them according to the different speech issues and the Portuguese language is a big challenge and an interesting opportunity.

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Attachments

Art Director Worksheet

Main Objective:

Define the art concept of the game

Define the style of the world and key elements of the game

Describe in detail the main character of the game

1. Define the presentational style of the game.

(cartoon, loonyToon, pencil drawing, photorealistic, manga...)

Low-Poly.

2. Define the aesthetic style of the game world.

(1950's science fiction, Medieval, Greek, Egyptian, etc)

Contemporary.

3. Define the lightning effect that can influence the gameplay, if there are any.

(fog, candle, moonlight, fire, lamps, mirrors...)

Direct sunlight and emissive textures.

4. Define the colour palette that will be use

(dark + blue = night, red + black = hell, bright primary colours = children...)

Bright primary colours (pastel).

5. Describe how people/creatures look like, if there are any. Describe their role through their appearance (young, sexy, ugly, friendly, nervous, evil, clumsy...)

The main character, Som, is a small and curious robot. It doesn't know how to speak, and it needs the player's help.

6. Describe how the user interface elements support the style of the game (buttons, clocks, lights, pointers, type fonts, sliders...)

The buttons are simple, minimalistic in design, and use the same colours as the rest of the game.

7. Draw the box of the game as it will look like in a shop.

Game Designer Worksheet

Main Objective:

Describe the Gameplay Modes

A. Primary Gameplay Mode.

Place where the player will spend most of the time

1. Setting

A green park with a bridge, park benches and a sail boat.

2. Perspective (1st person, 3rd person, etc)

3rd person (Top-down view)

3. Interaction Model (Avatar, omnipresent, etc)

Avatar (possessed character)

4. Challenges

Sound comparison exercises

5. Actions

The player can choose 1 of 2 possible answers.

6. Mechanics

As the player steps on a stage, the exercise shows up. Prompting the challenge.

C. Game Level

Describe a level that represents in the best way your game.

1. Work with the level designer so he/she can complete the level worksheet.

- Analyse the level layout
- Describe the starting condition of the level
- Does the game have a single victory or loss condition?

Describe the victory or loss condition, if there is one

The player can only lose a specific exercise, there is no loss condition in the level itself.

Describe the main challenges and actions

After listening to a sound, the user chooses an answer and depending on it, it will receive positive or negative feedback.

User Interface Designer Worksheet

Main Objective:

• Define the main actions the player must do and map the to the main input

control the game will use (Joystick, mouse, keyboard, etc)

• Determine the lay out of the screen of the primary gameplay mode

A. Input Control

Complete the section that best match your game control

(keyboard, mouse, gamepad, other)

1. Mouse

Define what moving around the mouse does.

An indicative green circle shows up on the maps surface, following the mouse's cursor position.

Define what does the Left Button does.

Selects the desired location (triggering the movement and shortest path choice). If in a stage/menu, selects an option.

Define what does the Right Button do.

Nothing.

4. **Touch controls**

   Functioning as a mouse. When the user touches a location on the map, it triggers the movement in the shortest path.

Level Designer Worksheet

Main Objective:

• Fluid communication with the Game Designer and User Interface Designer

• Create different scenarios that can challenge the player in different ways

A. LEVEL DEFINITION

1. Level Name

"Parque dos sons"

2. Level Description

(In one phrase describe the level. Ex: an industrial factory)

A public park, with an open area to explore.

3. Victory condition, if any

If 13 stages are successfully completed.

4. Loss Condition, if any

None.

5. Starting conditions

0 stages completed. If played previously, a record on the number of correct and incorrect exercises will already exist.

6. Key elements that makes this level different from others

The map size and its diverse elements.

7. Level description (describe and position the different elements and NPC that makes part of the gameplay)

Stages are scattered throughout the map. They follow a path that eventually crosses a wooden bridge and are even hidden in a small labyrinth of bushes.

Lead Game Designer's Team Worksheet

Teamwork Guideline

What do you have to do?

- **In charge of arranging the workload produced by the team.**
- **Keep the deliverable tasks on time**
- **Represent the team**
- **Handle interaction between the team members**
- **Assumes final decisions**
- **Make sure you keep the game simple**

1. The player.

What is the role of the player, who is he trying to be? Does the player have an avatar? (if it has, describe it, as well as any other character that appears)

The main character is young robot. The robot can’t speak, and the player must help it overcome that by solving the sound comparison exercises.

2. The World & Setting.

Where does the game takes place, how does it look like? Which is the interaction model (omnipresent, avatar)? Which is the Perspective? Define the art and musical

style. Which are the boundaries and dimension?

The game takes place in a colourful world. The locations consist of a house, park and square with several stores. The art style is low-poly (optimizing performance), and the musical style is minimalist (focusing on synthesisers and piano).

3. Challenges & Actions.

Which are the problems the player will face? Which are the moves the player will take to overcome the problems? This will define the rules of the game

The player must complete the stages that are presented to him. These stages contain sound comparison exercises, essential to complete the game.

4. Internal Economy

Define the resources that the player will use if they exist

None.

5. Victory or Lose Condition

Describe if it makes sense that you can win or lose the game. When does the game end?

The game doesn't end. The player should complete each sound comparison and obtain the best score possible, but it can repeat them as much as he/she wants to.

6. Gameplay

Describe the primary gameplay mode. Define the killer features of the game

3D game with predictable player movement, eliminating the standard onscreen buttons that are so common in mobile games.

7. Game Concept

Describe in a few lines what is the game about. It should transmit the main game idea, define the game genre, and how you play it.

Example: ""Annie the Ant" is a 3rd person shooter, where you control an amnesic ant that will have to fight against giant predators and organize her combat team to succeed their missions in the underworld**"**

"Mistérios do Som" is a top-down 3rd person serious game, in which the player controls a robot that can't speak, "Som". The player must help the robot by solving an array of sound comparison exercises, spread around the different levels.

Lead Designer's Section

Game Concept: Write down the game concept, maximum 5 lines

A 3D interactive board game. The stage trigger exercises that the player must answer to finish the level.

Story & Narrative

A robot can’t speak and the player must help him overcome that issue.

Describe what happens before the game starts

A small tutorial explains the plot and rules of the game

Beginning stage of the game

0 stages completed

Middle stage of the game

Reward stage

Ending stage of the game

Sound comparison switch

(English version) Inquiry *Mistérios do Som*:

1. **How old are you?**

a. 6 c. 8 e. 10

b. 7 d. 9

2. **Do you have or had any speech and language problem?**

a. Yes

b. No

3. **Do you know anyone suffering from speech and language disorders?**

a. Yes

b. No

4. **Would you like to play a fun 3D game that could help you pronounce difficult words?**

a. Yes

b. No

5. Would you like to change the robot's colours?

a. Yes

b. No

6. Do you have any difficulty pronouncing the following sounds?

a. P / B c. N / D e. D / G

b. F / V d. T / G f. B / M

7. How many words have you answered correctly?

a. 1 to 3 c. 6 to 9

b. 3 to 6 d. more than 10

8. Did you find the exercises difficult?

a. Yes

b. No

[all inquiries can be accessed here http://tiny.cc/xtlzyy]

Table – ClubeMath's inquiry results.

Ag	SLC	Knows someone with a SL	Interest in 3D game to aid ith SL	Character customizat	Difficulty playing the ga	Most difficult sound compari
7	N	Y	Y	Y	N	
7	N	N	Y	Y	N	P/B
7	N	Y	Y	Y	N	D/G
8	N	Y	Y	Y	N	P/B
8	(hearin	N	Y	Y	N	
8	N	Y	Y	N	N	
8	N	Y	Y	N	N	
8	N	N	N	Y	N	
8	N	N	Y	N	N	
8	N	Y	N	N	N	
8	N	N	Y	Y	N	
9	Y	Y	Y	N	N	
9	Y	Y	Y	Y	N	
9	N	Y	Y	Y	N	