A 3D Serious Game for Improving Social Skills of Children with ADHD via Rhythm-Centric Interactivity

Marina Giannaraki

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School of Electrical and Computer Engineering,
Technical University of Crete

Thesis Committee
Katerina Mania, Associate Professor, Thesis Supervisor
Georgios Yannakakis, Associate Professor
Elia Kourkoutas, Professor, Department of Primary Education, University of Crete

Associates
Nektarios Moumoutzis
John Papatzanis

Abstract

This thesis presents a multimodal 3D serious game named "ADDventurous Rhythmical Planet". The goal is to exploit the benefits of music and rhythm helping children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) to overcome their psychosocial challenges. Those children often face challenges regarding their social interactions at school and at play due to the characteristics of inattention, impulsivity and hyperactivity that may occur in their behaviour. That may lead to isolation, low self-esteem and even depression.

Additionally, music is shown to significantly help children maintain focused attention as well as offer a timed structure around their actions, involving melody and tempo. Music can also aid the development of cognitive ability, self-confidence and promote limits and rules. Through music, children can learn how to control their impulsivity, learn to pause and wait for their turn and apply such social skills to their every-day life.

In this thesis, the advantages of music are exploited using a tin drum. This drum is used by the player to produce rhythm. The drum is connected through a board named Makey Makey to the computer. This board sends each drum knock as mouse click signal to the computer. Using that, the player tries to reproduce a given beat, and subsequently synchronize with another player, and cooperatively produce an expected beat. That creates the connection between the real and the virtual world of the game.

The virtual world takes place in space at a musical planet and the main hero is an alien. The alien has crushed on the planet with its spaceship and needs to go around the planet to gather tools to fix the spaceship, to continue its journey. In order for the alien to progress in the game, the player uses the tin drum to reproduce the rhythms that are requested from him/her. The completion of each level results in a virtual award, which is acquiring a tool in the player's virtual suitcase. After completing the single-player mode, the player moves on to the multi-player mode. In this mode, the two players will have to hold hands and use the tin drum to collaboratively reproduce the requested beat.

The development platforms used to fulfil the needs of this thesis, were the Unity Game Engine, and the Blender graphics software. For the input management and comparison of rhythms, a novel algorithm was implemented in cooperation with an expert musician who established the rules and restrictions of this issue. This algorithm takes the beat created by the player and compares it to the expected beat. The outcome of the algorithm is for the player to complete the level if the rhythms were similar enough or that the player will have to try again to achieve a more similar beat to the expected. In each case, the player receives a visual representation of the beat that he/she played showing the correct knocks and the false ones.

In conclusion, this game brings the children together in a friendly and fun environment and creates favorable conditions that motivate them to socialise and cooperate. The aforementioned game is innovative as it combines the use of multi-player mode, with the benefits of music and rhythm in order to enhance social skills and collaboration.

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1 Introduction

This thesis is implemented along the lines of the undergraduate degree for the School of Electrical and Computer Engineering in the Technical University of Crete.

1.1 Motivation

To begin with, serious games already exist in education and are showing promising results the past few decades. Specifically the use of sound, picture and instant feedback can provide an effective learning experience. These types of games, are also shown to be helpful for children with special needs and more specifically children with ADHD. The existing games, however, aim mainly on improving the symptoms of children with ADHD, while this thesis aims in improving the psychosocial issues that these children face, and adds the factor of rhythm which creates a completely innovative description of a game.

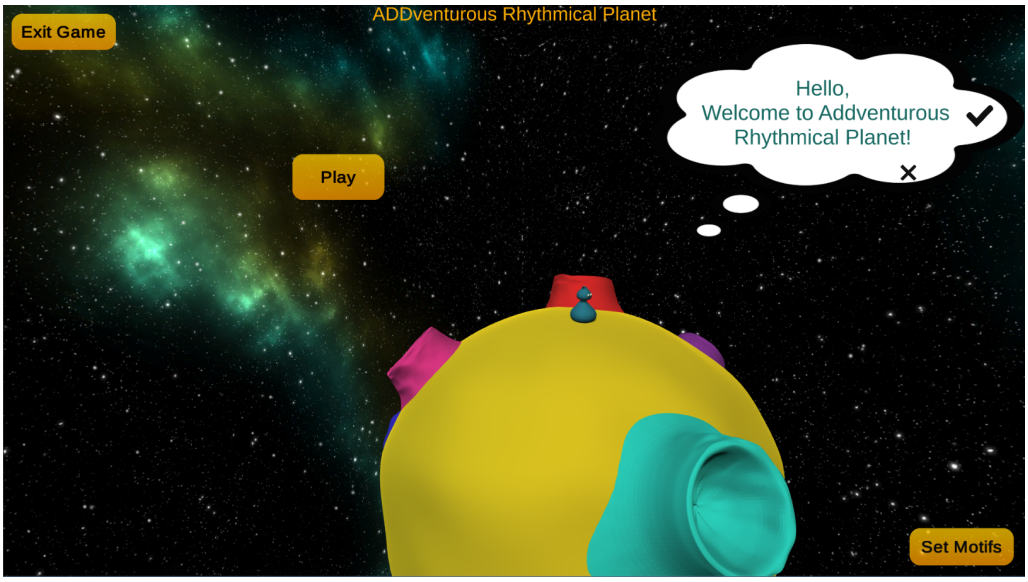
The main purpose is to create a 3D serious game for children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) of 8-12 years old, aiming to improve their social collaborative skills using rhythm and music. This game is played by children with ADHD and non-ADHD children with the aim for inclusion and collaboration between the two. This idea came up from the increasing awareness regarding ADHD and from witnessing the results of using rhythm as a learning method during a rhythm related seminar. Simultaneously, music therapy, an especially rhythm seems to be a very effective mean for the improvement of different skills in special education. Due to impulsivity and hyperactivity, those children tend to have poor collaborative skills such as the tendency to interrupt and not wait for their turn. This game's purpose is to improve those abilities.

The design process that was followed consisted mainly of numerous brainstorming sessions as well as counselling by psychologists, special education teachers, and the musician Mr John Papatzanis who is an expert on musical rhythm and suggested to employ rhythm as the main form of user input in the game. The main idea is that children will produce rhythm patterns using drums. Such actions will be translated to game play progression in the game environment. This idea was based on the material that Mr John Papatzanis employed during extensive rhythm seminars that he has taught to educators in relation to how to incorporate rhythm in their classroom teaching activities. The educators applied rhythm practices in their classes without digital material and have reported positive results in relation to enhancing collaboration, learning and a sense of fun in the class. These Rhythm related practices are integrated in the presented game using playful and fun ways and will be followed by Pilot testing in schools.

1.2 Contribution

This game, The "Addventurous Rhythmical Planet", takes place in space, where the main character of the game is an alien, who's spaceship crashed on a musical planet. The crush resulted in the pieces of the spaceship scattering and falling inside the craters of the planet. The aim of the game is for the player to help the alien find and retrieve the pieces of the spaceship, to repair it and continue its journey. The users tools are a tin drum, which will be used to create the music that the craters will request in order to give the alien each item. The other tool is a bracelet that makes this communication possible, without which, the craters cannot hear the music from the tin drum.

When starting the game (Figure 1), the main hero provides a small story and instructions to the player via a pop up dialogue. Then, either a new player needs to be created by completing a name, year of birth and if there is ADHD diagnosed, or an existing player can be chosen from a list. There is also a menu in which the instructor can change the rhythm motif that will be asked from the player. After choosing a player, the player chooses whether to play in single-player mode or multi-player. It is advised for the player to first complete the single-player mode to get better acquainted with the environment and the rhythm and then go to the multi-player. After choosing mode, the player sees a panel that shows what color is the crater that corresponds to each level. The player needs to go to the chosen crater, using the arrows of the keyboard, to enter this level. This creates a sense of adventure and interaction with the player even before the game has started. When the player gets to the crater, the corresponding scene of the game loads and the player receives instructions as to how to play the game.



(a) Main Scene of the Game

(b) Level 3 - Multi-player scene

Figure 1: The Main Scenes of the Game

After the instructions are given, the game plays the requested beat, using sound and glowing small craters. Proceeding that, it is the player's turn to try and play the beat using the tin drum. Afterwards, the game decides whether the effort gets accepted or not by show in the result in a result panel with colored circles that represent each requested knock. When a circle is cyan, that means that it is an accepted knock, and when it is orange, it isn't. There should also be noted that a set of buttons exist allowing for the player to return to the previous scene, hear the expected beat again, hear the beat that he has created and try again on command. Apart from this panel and buttons, a pop up dialogue also shows up telling the player if he completed the level or needs to try again. If the player needs to try again, the requested beat will be heard again and then will be the player's turn again. If, however the level is completed, the main hero acquires an object at his/hers suitcase, which happens by the object lighting up in the color of the crater

of the level. That is the reward given to the player on each level, an tool or part of the spaceship.

When the player acquires them all, the spaceship can be fixed and the alien can continue its journey to other planets. After the player gets the item, he/she returns to the main scene to go to the next level and continues playing the rest of the levels. When on multi-player mode, two players need to collaborate to create a given beat. A panel named "Who Plays What" decides which knocks will be played by which player and indicated by using colors in a similar way as the result panel setting a color to each player. This mode of the game continues as the single-player mode as well. The players receive a unified result making this a team collaborative effort.

All the models of the game are original and were created in Blender and for the implementation of the game, the Unity platform was used. The board that takes the tin drum's beat and sends it to the game, was Makey Makey, a board that uses closed loop electrical signals to send the computer the signal of a mouse click. An important part of the algorithmic process was the comparison between two rhythms and the decision whether those rhythms were similar enough. The criteria used for this algorithm were given by the musician John Papatzanis.

This game was created to help children with ADHD become more collaborative with their peers. In the first level children get familiar with the game environment and the use of rhythm in the game. The second level promotes collaboration through interactive techniques. That way, children learn to wait for their turn, help his/ her playmate and accept guidance from him/her in order to complete the levels and win the game.

Finally, a pilot evaluation took place to review and check the first impressions of children 8-12 years old and teachers. This evaluation showed that the children were very impressed with the environment, and very excited to play the game. The majority faced no particular difficulties and they were all motivated to play the multi-player mode. They also gave some suggestion for improving the game. Adding to that, no children dropped out, they all stayed and finished the game, which means that they all remained focused for at least twenty minutes. In regard to the teachers, they too were intrigued by the environment and noted that the children would be attracted and engaged by the game. Also, they considered that the multi-player game could promote collaboration in an original and entertaining way. The difficulty of the game was deemed of medium level. Finally, the educators offered suggestions and ideas for improving the game and expressed their interest in using the game in the classroom.

1.3 Thesis Structure

This thesis is divided in 7 Chapters. The first Chapter is the Introduction that contains a brief summary of this thesis explaining that it is the implementation of a game for children with ADHD aiming to promote collaboration using rhythm. It is also mentioned how Mr Papatzanis' vision was formed into a game. Also briefly explains the story of the game placed in space and how the tin drums are used in the game. This Chapter also contains the present Chapter.

The second Chapter, is the Theoretical Background that this thesis was based on. It explains the definitions of ADHD, Music therapy, serious games and how they are connected to this work. Also, this Chapter showcases other games aiming to children with ADHD and how they differ from the present one.

Afterwards, there is Chapter Chapter 3, the Software & Hardware Architecture and Development. This analyzes the software platforms used such as Unity platform, the Blender software and their basic characteristics. Also, it explains the boards and sensors used for this project and how they are associated to the game.

Then comes Chapter 4, the User's Experience, which explains everything a used would like to see and know about the game. Starting that this game takes place in a planet with an alien as the main hero, also how rhythm is used. Also it gives a clear view of the flow of the user interface and how craters are used as a portal to the levels and also the process of playing the game with a tin drum.

Chapter 5 is the Implementation of the game, which analyzes in detail how the Addventurous Rhythmical planet was created from the beginning. Starting with the input of the game and how the sensors where used to how the craters of the game are used as a portal for the levels. Also explains using diagrams the algorithms of how the rhythms are received, used and compared, and everything related to how this game's single-player and multi-player mode were constructed..

After that, follows Chapter 6, a Pilot Evaluation of the tool, where two questionnaires where given in children and educators. Every filled out questionnaire is recorded and explained. Finally, the questionnaires are analyzed and the first impressions of the experiment participants are analyzed.

Finally, there is Chapter 7, the conclusion of this thesis. This Chapter draws the conclusion of the current work, and how this thesis is considered a successfully implemented game. Moreover, the future work that is suggested to be done is addressed in terms of further implementation, an extensive evaluation and alternative environments for the game to take place in. After those, are the Acknowledgements, Bibliography and Appendix of the thesis.

2 Theoretical Background

This Chapter is going to analyze the theories in which the creation of this game was based upon. More specifically the definition of ADHD, Music therapy and its benefits, as well as that of Serious Games, will be decomposed. Concluding this Chapter, there is a brief presentation of the recent work that had been published related to this work.

2.1 Definition Clarification

2.1.1 Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) is defined as a behavioral disorder with a wide range of symptoms that can appear from the age of 7. Taking that into regard, the game refers to children from the age of 8. There are three types of ADHD: Inattentive, Hyperactive, and Combined [1] [2] [3]. The Inattentive type's main problems are limited attention span, forgetfulness and distractability. The Hyperactive type's problems focus on the inability to sit still for a certain period of time appearing restless. The Combined type's issues are the combination of the two previous types.

In order for a child to get diagnosed with ADHD, it is required that is has six or more of the DSM IV symptoms [4], persistent for at least six months. In detail, those symptoms need to originate from the complex of symptoms of the Attention Deficit section, in order for the diagnosis to be Attention Deficit Disorder, and respectively for the hyperactivity disorder section. The severity of the symptoms vary to each person.

2.1.2 ADHD in children

Since ADHD can be diagnosed from the age of 7, there are many issues that originate from this disorder and can be managed with the aid of specialists and educators. These issues cause problems not only at school but also at home as well as during the child's social interactions. For example, the child cannot sit still at the class, or pay attention at what the teacher is saying. Their social relationships are challenging because they tend to interrupt their peers before they finish what they are saying in order to add or say something irrelevant that came to their mind [5] [6]. Additionally children with ADHD cannot comply with limitation and boundaries, sometimes have low performance at the school environment and even face difficulties with their social relationships. Sometimes, due to their hyperactivity and impulsivity, they may show aggressive behaviour which leads to conflicts with their peers. [7]. Thus, the present study focuses on the reinforcement of the social skills of children with ADHD and particularly in improving their skill of collaboration. [8].

Emotion management, behavioural management, self control, self regulation and inclusion are some of the most popular intentions of people who deal with people with ADHD [9]. Thus, the game that is analyzed in this thesis aims to help children with ADHD collaborate with other children, on a playful ground, using the benefits of rhythm and music. This thesis was inspired from these seminars, which open up a path for collaboration with Mr Papatzanis using the same element and principles that are applied there.

2.1.3 Rhythm for Learning

Rhythm doesn't have a generally accepted definition, however, it can be described as "*the order in the movement*" [10]. Rhythm is a vital part of music, and on its own is considered be of great importance in improving attention and learning in both adults and children [11].

As an educational concept, rhythm is inextricably linked to man, as well as to a large extent to modern pedagogical and professional innovations in a number of fields, which consider musical rhythm a beneficial element for increasing professional performance and productivity, as well as the spirit of cooperation, when applied as a seminar training [12], [13].

The methodical and targeted participation in processes of promotion an cultivation of rhythm is considered to contribute to the development of motor skills, coordination and synchronization skills and the development of active listening to music (musical education). This also leads to improvisation, which is quite important for the cultivation of communication, expression of self and imagination. Improvisation is especially important for the creative and psychosocial skills, when applied in group activities such as school [14].

That is what John Papatzanis, expert musician and percussionist, endorses in his seminars of rhythm and percussion. He considers music to be of great assistance in the process of leaning and make a big difference in how students perceive education. Apart from that, Mr Papatzanis feels that there is no person that can't learn rhythm and that it is an element fundamentally bound in our existence. By playing a beat and learning to repeat it, there are more lessons learned than rhythm. The students learn to listen, pay attention and wait for their turn. After personal experience of the researcher in Mr Papatzanis' seminars, the inspiration of using rhythm to create a game to help children with ADHD arose. The vision that this game is based on, is Mr Papatzanis' idea to take advantage of the fact that children can easily focus and spend time playing a video game, and by taking this aspect of video games to create a medium that could help the parents, teachers and other children collaborate with each other and improve their social skills and even concentration.

2.1.4 Music Therapy and How it Helps

Rhythm is a fundamental element used in music therapy. Music therapy is a sort of a creative psychotherapy of many forms such as listening to music, learning and playing a musical instrument and singing. Music therapy aims to improve attention, reduce hyperactivity, externalize feelings and improve mental health [15].

It is important to point out that music is a mean of communication that is part of our existence and gives the chance for interpersonal experiences of sharing [16].

Therapy with music and movement is very efficient with children with various disabilities and can be used as a strategy in order to achieve well being for the children and their families [17]. These are the grounds that this thesis is based upon, to create a game that uses rhythm, aiming at improving social skills.

As a result of this, children diagnosed with ADHD could train their brains to achieve higher levels of focus and self-control by listening to and interacting with music. Self-confidence can also play a vital role during the social life of children with ADHD because they usually compare themselves to the other students and due to their differences, they end up feeling inadequate or inferior to the rest. Other

students may result in bullying practices enhancing social marginalization. So, by acquiring self-confidence, they can express themselves, make friends and show their talents. In relation to understanding limits and rules while learning music, they will have to comply with a large amount of rules in order to advance in making and understanding music. Through this process, they will grasp the necessity of rules and later learn to understand social cues and respond accordingly to them. Rhythm and music can also be incorporated during studying which children with ADHD find extremely challenging bringing great improvements in concentration, as well [18]. Music therapy uses the elements of music such as rhythm, to improve social, communication, cognitive, academic, emotional and behavioural skills [19]. The advantages of music therapy is that it requires no prior knowledge of music, it does not involve the feeling of failure and it promotes creativity. Also, it is important that the child does not have to be musically inclined in order to select this kind of therapy. As a result, when it comes to children with ADHD, music therapy bolsters attention and focus, reduces hyperactivity, and strengthens self-confidence and social skills. [20] [21] [22]

2.1.5 Serious Game

Over the past decades, serious games have been proven to be an efficient way of taking unpleasant, difficult and even boring tasks, into playful and and engaging ones, in education, and training. There are numerous definitions regarding serious games, depending on the area in which they are referring to. A study that summarizes the fundamental meaning of term, is that *"serious games are (digital) games used for purposes other than mere entertainment"* [23]. Many researches have indicated that the different applications of serious games can have a vast number of benefits for the users, both children and adults. Some of them are, learning social-emotional skills, upper limb rehabilitation following stroke, and crisis management training [24], [25], [26].

2.1.6 Serious Games in Education

Serious games are part of a greater term, which is the multimedia environments. These environments use sound, image, text, and motion pictures creating an interesting experience for the user. The use of sound and picture make the entire process more fun. The motion pictures help children focus their attention while having an active role in this process. This kinds of multimedia games, provide feedback at a small amount of time, which can have instructional or helping content. Furthermore, the user has control of the whole procedure [27].

Regarding the advantage of instant feedback that games provide,it seems to be really helpful for children's learning performance [28]. For this reason a game will have positive results to children with ADHD because they respond better to short immediate feedback communicated continuously after short periods of time in contrast to feedback communicated at the end of a longer task.

According to [29] serious game have different aims in education and can be used to achieve various pedagogical aims. Some of these are to be able to *provide effective learning experiences* [29]. These kinds of games are often multi sensory and include the elements of image, sound and movement. This way, an attractive environment for the child is created, resulting in lower possibilities of frustration

(defeat). Simultaneously, the chance of repetition increases the possibility of success [27]. Given that children with ADHD have an increased level of distraction, a game that attracts attention using audiovisual and movement, can achieve higher levels of focus, and therefore higher chance of learning. Moreover, video games effectively engage players in a loop of actions during play. That loop is: understanding - taking action - checking if rules are applied - receiving feedback [30].

Recent studies have indicated that serious games can be effective for children and adults with special needs. Due to their attractive characteristics, they can result in a variety of positive results in cognitive, emotional, social and motion-sensory abilities. Specifically, regarding autism, the use of serious games showed that training on emotion recognition and social skills can be achieved [31]. Another interesting study of serious games, was one that was created in order to help people with down syndrome adopt healthier eating habits [32]. Similarly, a serious game of everyday life like images is very attractive to children with down syndrome [33]. Another interesting use of serious games, is identifying learning disabilities, such as dyslexia, in early school years [34], [35].

As a result a serious games seem to be suitable for children with ADHD. The attractive and interactive environment will gain the interest of the student. Instant feedback will increase the child's interest and reduce the chances of drop out. It is very important to communicate to the player what went wrong in the case of a negative feedback, so that they can improve themselves. So, the feedback provided in serious games is usually frequent and instant in relation to the action that the player takes during gameplay. The control of the process..that is given to the user gives to children with ADHD the opportunity to make mistakes and correct themselves at their own pace without judgment. In reference to the loop of actions process during play, it helps people diagnosed with ADHD understand what they did wrong and focus in order to become able to get the positive feedback that they seek. This process improves their training in specific activities. Therefore, the need to include that helpful loop into any game targeting training of children with ADHD is imperative.

Having established all of the above, there is a need for a serious game for children with ADHD , that will attempt to help improve their social collaborative skills using rhythm as a medium, for the ages 8 to 11 years old.

2.2 Related Work

In the recent decades, various studies have taken place, regarding children with ADHD. Those studies indicate that serious games make a huge difference in their everyday living and school attending.

Digital games for children with ADHD target either the diagnosis or the improvement of skills that occur due to ADHD. Such games are developed according to children's age, usually for either 6-8 or 8-12 years old. Games targeting symptoms' improvement usually address hyperactivity, impulsivity, inattention, and working memory. Additionally they aim to improve cognitive flexibility and inhibition control as shown below.

A relevant research has put forward an interesting game named *"Adventurous Dreaming Highflying Dragon: A Full Body Game for Children with ADHD"* [36]. This game consists of three mini-games that each help the child to work on different problems that it is facing due to diagnosed ADHD. The first one offers a space to practice attention and wants to improve the ability to focus and remember specific visual prompts. The second one tries to enhance gross and fine motor skills. The third one trains the ability to hold still on one pose for a specific period of time, aiming to control impulsivity. A game preview can be seen in figure 2. This game requires full body engagement of the player. The idea of this game is to improve ADHD symptoms, by inspiring goal planning and dedication.

Figure 2: Adventurous Dreaming Highflying Dragon

Similarly, the game named *"ANTONYMS: A Serious Game for Enhancing Inhibition Mechanisms in Children with ADHD"* [37] also includes three mini-games. The first two mainly help on children paying attention to details which are significant for gameplay and the other one on inhibition and control of impulses. The ANTONYMS game, apart from its use as a rehabilitation tool, it can be also used as an assessment tool. It is designed for a personal computer and the interaction with the player is through a touch screen. The general goal of this game is to improve the children's ability to keep their attention focused in their everyday lives. In figure 3, a screenshot of the game can be seen. The preliminary results show that the activities that are implemented in the game, address impulsivity and inattention [38].

Moreover, the *"ChillFish: A Respiration Game for Children with ADHD"* [39] focuses on breathing exercises and how they can help children with ADHD to control their stress level. Based on an engaging gameplay, it becomes easier for children to sustain their attention throughout these exercises. ChillFish is controlled by the player breathing into a sensor-mounted LEGO fish. A glipmse of the game can be seen in figure 4 The player, using the puffer fish tries gather as many starfish as possible. The results of this work, where that ChillFish can aid the player in

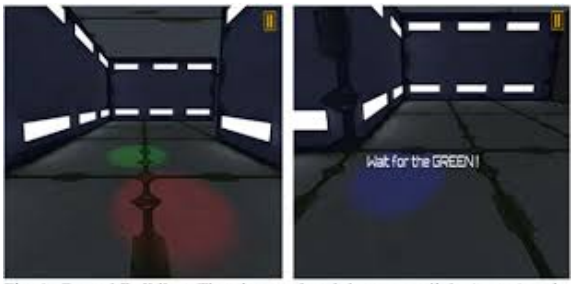


Fig. 1. Central Building. The player missed the correct light (green) and

Figure 3: Antonyms

achieving a calm state, just like the one that the traditional breathing exercises do.

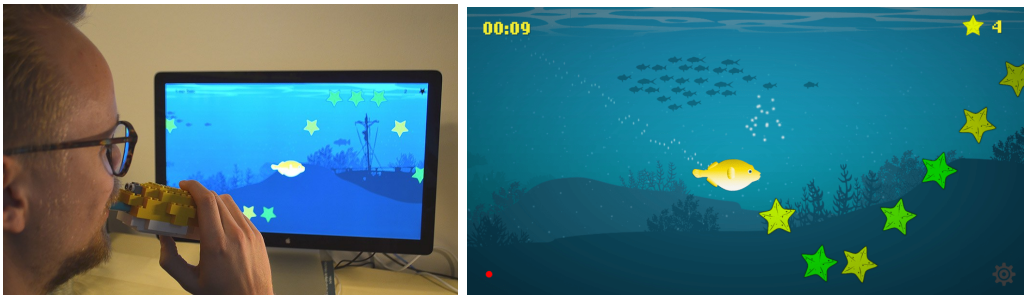


Figure 4: ChillFish

The EVO Project [40], [41] aims to help kids concentrate by thrusting them into a world where they have to make split-second decisions. This engages the brain and trains it to tune out distractions, thus, allowing a child to focus completely on the task. These tasks include guiding an alien spacecraft through a canyon, among other things. To move the ship, players need to select the red fish that appears on the screen while ignoring blue birds and green fish appearing at the same time. The Evo game detects the player's skill level and as the game progresses, it gradually increases the speed of the ship and the number of objects the player must hit such as adding blue birds to the mix. A preview of the game can be seen in figure 5 The results show that this can improve attention, working memory and inhibition in children with ADHD. However, there seem to be positive results on executive tasks similar to the trained tasks, but generalization to other tasks seems limited.

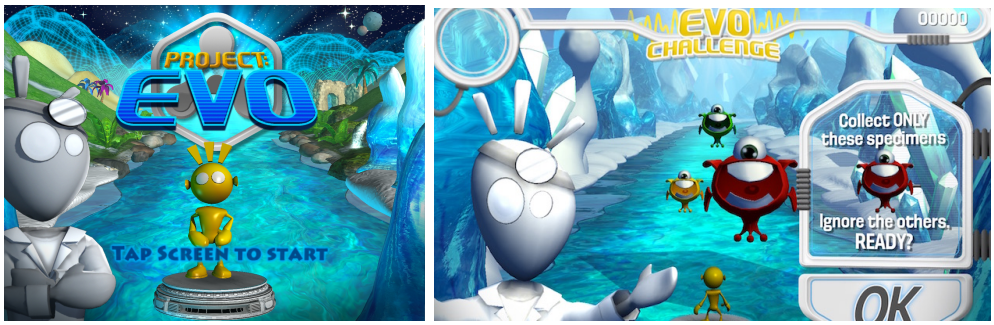


Figure 5: Project Evo

In addition, *"Plan-It Commander"* [42] is another serious game regarding children with ADHD. This game was especially created aiming to foster behavioural

learning, regarding the use of strategy in everyday life. The game contains three minigames with increasing difficult, and the goal is for the player to collect rare minerals. The first minigame focuses on time management, the second on planning ahead and breaking down tasks into smaller pieces, and the third one on helping teammates and having a more positive social behaviour. An idea of what the game looks like is given in figure 6. The user satisfaction survey showed parents and students to be quite satisfied with the game and they would recommend it to other parents and children with ADHD.

Figure 6: Plan It Commander

In conclusion, the games analyzed above are expected to a have positive impact on children with ADHD. That is one of the main factors that drove this research at the direction of creating a serious game for children with ADHD. Those pre-mentioned games mostly employ the visual sensory modality, requiring children to interact with mostly visual worlds and related game play. In this thesis, we will introduce the added training benefits of including music and rhythm as essential components of the game play, engaging vision, sound and motor actions in a collaborative interactive experience. We hypothesize that this game will enhance the social skills of children diagnosed with ADHD based on the fact that ///CITE/// games aiming to improve the basic symptoms of ADHD don't have any generalization to the children's everyday life.

3 Software & Hardware Architecture and Development

3.1 General Architecture & Hardware

This game was created under the roof of the Technical University of Crete, in the MUSIC Laboratory (Lab. Of Distributed Multimedia Information Systems And Applications) under the supervision of associate professor Katerina Mania.

The Unity real-time development platform is used as the basic implementation environment of the game. The game's central interaction affordances are happening through a drum-like object that the players are using to create rhythm. In search for a reliable and versatile medium to receive the knocks of the drums and transmit them to the computer, two different architectures were implemented. One using an ESP8266 microchip and a piezoelectric transducer and another one using the Makey Makey board.

Starting with the first, in order for the drum actions to be communicated to the visual environment of the game, a sensor was required, as well as a device to transfer the data from the sensor to the game. The hardware used is a pressure detection sensor (piezoelectric transducer) connected to an ESP8266 board on each drum as shown in Figure 7. WiFi is used so that the drums can be used independently. Drum actions and identification data are transmitted to the visual environment of the game for each drum stroke as well as a number representing a percentage that signifies the loudness (force) of the drum strike. Timestamps are used to detect the beats (rhythmic patterns) and compare them to target patterns that the players need to perform, as close as they can, in order to advance in the game. For the communication of the ESP8266 with the Unity platform, a basic http server is set up to receive the information regarding drum strokes. Each drum stroke is represented by a unique id used to identify each individual drum, the timestamp of the stroke and its loudness.

Moving on to the second architecture, while recognising the difficulties that the ESP architecture posed, another board named Makey Makey seemed to promise that it could be used more accurately. Using this board, connected to the computer through usb cable and to a tin drum-like surface, and the user using a metal covered bracelet connected to the "ground", an open circuit is created. As a result, when touching the tin drum the circuit closes and the signal is sent to the computer. This architecture is shown in Figure 8.

The signal taken as an input the performed rhythm, which is converted to timestamps that is then compared to the expected beat and a decision is made on whether the player's beat is similar enough to the target rhythm or not. If it is similar enough, then the game progresses, or else the player needs to try again until he/she achieves the expected result. The target rhythm is provided by an expert musician. Furthermore, the expert musician provides the rules that need to be obeyed in order for the player's rhythm to be perceived as resembling to the target rhythm, taking into account expected inaccuracies made by novices. The similarity measure is finally refined, based on the analysis of the distances between the drum strokes and the comparison between the input rhythm and the rhythmic samples. This results to a set of results that represent the correctness of the input rhythm.

The second architecture was proven to be more reliable, with no delays and

Figure 7: Architecture of the game using ESP8266 & sensor

accurate during the transmission of the data. As a result this was the one used in the final implementation of this game. The implementation of the first one still remains in the final project, hoping that in the future the issues will be resolved and a wireless version of the game will be available.

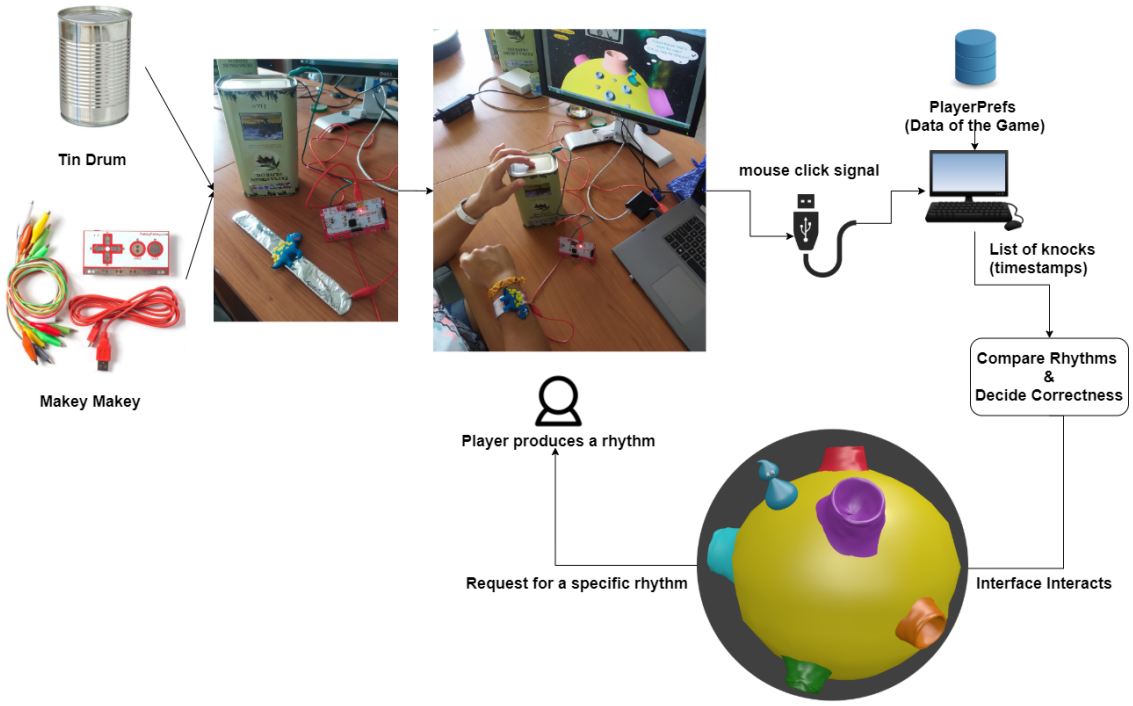


Figure 8: Architecture of the game using the Makey Makey board

3.2 Unity Game Engine

Figure 9: Unity Platform logo

At the present thesis, a serious game was created in order to engage children with ADHD. With the aim to make this game as attractive and playful as possible, a 3D platform was deemed necessary. The Unity Platform was chosen. The ADDventurous Rhythmical Planet was wholly developed in Unity, across-platform game engine. The version used for this game is 2018.3.1. Through this platform, the User Interface of the game, as well as the functionality of the game where created.

Unity 3D is a platform that gives the users the ability to create gaming environment in both 2D and 3D as well as drag and drop functionality. Additionally, over the latest years, the popularity of this platform has risen significantly, making it a mainstream tool for gaming development. Furthermore, this platform enables the use of 3D models from other sources, as well as the creation of a local server. Another great advantage is that Unity has an asset store available, where developers can purchase useful 3D objects, UI objects, and greatly useful plugins and extensions that can be used unedited or modify them in order to fit the game's needs. Also, Unity has a vast community that makes it easy for any developer to learn how to use it and troubleshoot any bugs. The online resources are multiple and there are also forums to share concerns, questions and ideas. Finally, Unity is available for free to any developer, in contrast with the other well known game engines such as Unreal Engine and CryEngine.

Another great asset of this platform is that it is a Multi Platform. It offers the creators the ability to move one game from one platform to another with minimal effort. Platforms such as iOS, Android, Windows Phones, Macs, Pcs, Steam, Playstation, Xbox, Wii U are all supported. Also, the scripting languages that are available in Unity are Javascript and C#, two very popular and manageable languages. The ability to create 2D games and Multiplayer Games is given in this platform as well. A really special asset of Unity is that it is relatively easy to learn for the wide range of implementation it provides. Also, there are several online courses and tutorials available, teaching the basics of this platform and making it easy to get started individually. The ease of use, can also be found during the process of creation, as the programmer can see the result of what he/she is working on in the editor without having to wait for the game to compile and build.

The Scripting ability of Unity was of vital importance since scripting is an essential ingredient in all applications. Scripts are used to make applications respond to input from the player and to arrange for events in the gameplay to happen when they should. Beyond that, scrips can be used to created graphical effects, control the physical behaviour of objects or even implement a custom AI system for characters in the game. This ability was widely used during the implementation of this priject.

Furthermore, in this thesis, a very basic ability that Unity offers was also used, and that is creating prefabs. A prefab is a GameObject turned model, that can include all the components of the gameObject and can be used repeatedly to create an identical GameObject in the same or a different scene.

3.2.1 Unity Interface

Moving on to the Interface of Unity, shown in Figure 9, there are plenty of windows seen at first.

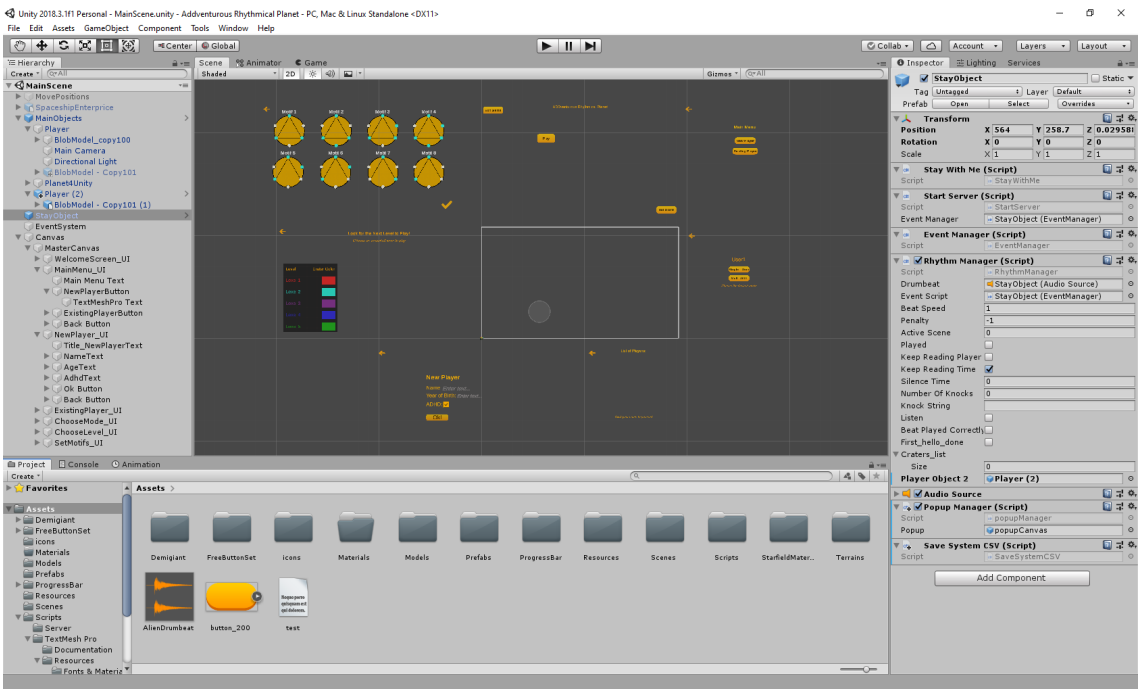


Figure 10: Unity Interface

"Hierarchy" is on the furthest left by default, and this show a list of all the

GameObjects in the open scene. This makes it easy for the delveloper to quickly locate and select any aspect of your game in order to change its properties. GameObjects are simply the elements that are included in the game.

"Scene" is the biggest window in the middle of the Unity software. This shows a view of the current level, menu, or game currently loaded in the platform and it is called a scene. This window is where the developer can drug and drop, move, enlarge and shrink GameObjects. The icons found along the top left of the Unity software change the way the user can interact with GameObjects and the scene. The hand allows for drugging around the view, whereas the arrows mode the objects in 3D space along three axes.

"Game" is the window hidden behind the Scene window and can be accesed by hitting the tab along the top. The game view shows the view of the scene as it is seen in the game. That means that it gives the perspective of the camera and in that window nothing can be moved around. This is where the game plays when testing it.

"Asset Store" is also found on the next tab ans gives access to assets that have been developed by the community.

The "Inspector" is a very important window found on the furthest right of the UI. The "Inspector" lets the user view and edit the properties of a selected GameObject. That could mean changing its size (scale) or position (transform), or it could mean adding components such as C# script, colliders, or Audio sources.

The "Project" window is found at the bottom of the screen and shows all the files that make up the game. This is where the user creates C# scripts and then selects them to open. Also, 3D files or textures can be drug and dropped for use in the game.

Finally, the "Console", the tab behind the Project window, is where the developer can see information from Unity itself. This lets the developer know if there are errors or warnings in the code, or show messages created to show information, created during the scripting process.

3.3 Blender Graphics Software

Figure 11: Blender Graphics Software logo

In order to create an original environment and an interesting and playful character, as described by the story of the game, Blender graphics software (figure 11) was chosen. Blender is a free and open-source 3D computer graphics software toolset for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, as well as virtual reality and computer games. Additionally, this is a very popular open source program, with many enthusiasts, and a large community developing, making tutorials and answering questions on how each tool works. Furthermore, this software was relatively easy to learn and it offers a

highly impressive 3D modelling and sculpting toolset. Specifically to this project, through this useful software, the 3D models of the planet with its craters, the small craters used for indicating the beats that the player creates and the main hero of the game where created. Additionally, the animation of the player was also created using Blender.

3.4 ESP8266 microchip & Piezoelectric sensor

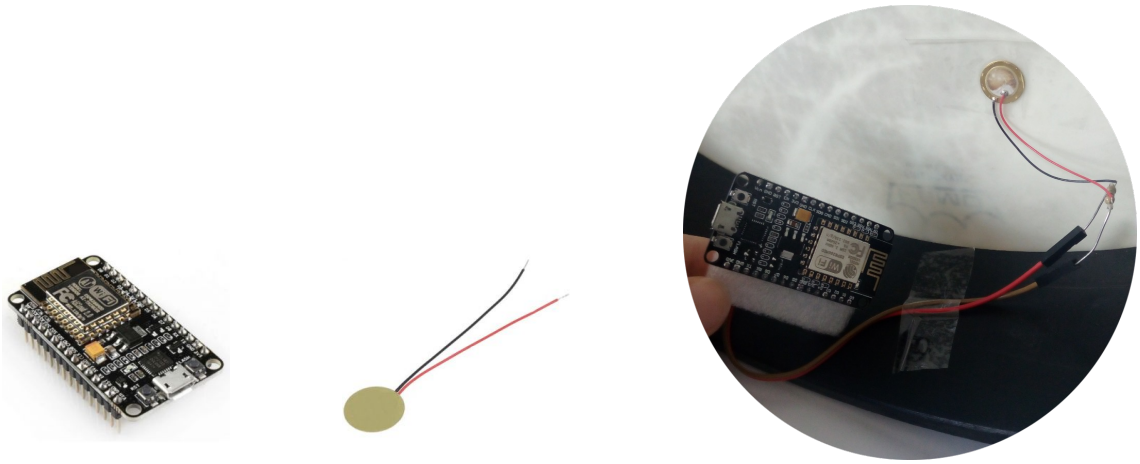


Figure 12: ESP8266 & piezoelectric sensor & their Circuit on a drum

For the needs of this thesis, a sensor that could identify the drum knocks and a chip that would be able to send that data preferably in a wireless way were needed. For this reason, a piezoelectric crystal was selected. This kind of sensor uses piezoelectric effect to measure changes in pressure. That sensor was connected to an ESP8266 microchip, a low cost WiFi microchip, with a full TCP/IP stack and micro-controller capability (Figure 12). Many efforts where made, but this circuit didn't perform as expected. There where problems regarding the loss of some knocks, as well as the factor of some delays that where lessening the experience of the game. As a result a new mean of connection needed to be found.

3.5 Makey Makey Board

Figure 13: Makey Makey Board

The Makey Makey board is designed to connect everyday objects to computer keys. Using a circuit board, alligator clips, and a USB cable, Makey Makey uses closed loop electrical signals to send the computer either a keyboard stroke or mouse click signal. This device is connected to a tin drum-like surface that allows for the signal to get transferred instantaneously, without any delays of missing signals. Using this, the user using a metal covered bracelet connected to ground, becomes part of an open circuit because it is connected to Makey Makey, just as the bracelet is as well. As a result, when touching the tin drum the circuit closes and the signal of a mouse click is sent to the computer. Then the computer uses the mouse clicks and interprets them to drum knocks and that way records the player's beat.

4 User's Experience

4.1 Main Features of the Game

Rhythm includes the ideas of geometry and consistence [43] that can significantly help a child with ADHD function in a more structured understanding and way of thinking, serving as a learning tool for multiple courses. Collaborative drum playing based on rhythm patterns offers decompression of stress and excess tension since it requires concentration, expression through a creative process and allows the child to stand up and move around. The "ADDventurous Rhythmical Planet" is based on a specific engaging storyline involving planets and aliens, communicated to the players. The players understand the concept which provides a solid motivation for them to be engaged with the tasks at hand.

4.2 Game Play

The players are using a drum to create a rhythmic pattern. The drum actions are translated to game play actions in the visual environment of the "ADDventurous Rhythmical Planet". The game progresses only if and when the player reproduces the target rhythm requested each time continuing its journey to the next stage of the game. The levels have an increasing difficulty.

The "ADDventurous Rhythmical Planet" has two modes, a single-user mode and a multi-user one. The game plot motivates the player to move from the first mode to the next and collaborate with other children. Also, through the single-user mode, the player learns how to use the tools of the game and practices, by helping the hero of the game, on identifying rhythm patterns and how to reproduce them. In multi-user mode, the players have to cooperate and collaboratively create rhythm in order to complete their mission. As a result, each player, in collaboration with the others, is able to achieve a common goal and learn the value of team work. Based on the design of the game play, children get the opportunity to feel closer to one another and cooperate.

The overall storyline of the "ADDventurous Rhythmical Planet" is centred around the main character, an extra terrestrial 14, who crashed on a foreign planet. It now has to move around the planet from one game level to the other. The different parts of the spaceship have fallen inside the craters of the planet. In order to acquire the missing parts, players will have to play the beat that each crater requests. In other words, completing a game level involves players performing specific rhythmic exercises with the drum.

The players' goal, is to find the parts of the spaceship that went missing. In the single-user mode of the game, when completing each level, the character will be acquiring a part of the spaceship. In the multi-user mode, when completing a level, the main character and her friends will get a new tool to help them repair the spaceship and to continue their journey.

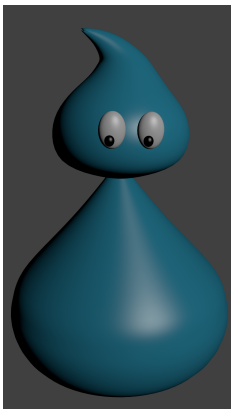


Figure 14: Main Character of the Game - All the 3D models of the game were created using Blender, a 3D computer graphics software toolset

4.3 Game Environment and Learning Activities

The environment of the "ADDventurous Rhythmical Planet" consists of a main menu, a Players' board, and also a user selection interface between single- and multi-user mode as shown in Figure 15.

Figure 15: Menu Diagram 1 - Choosing Player

When the game starts, the player sees the Main Screen, in which the main character of the "ADDventurous Rhythmical Planet", the alien, welcomes him/her to the game, tells the story and asks for the players help in this journey. The buttons existing in this stage are the "Exit Game" button, the "Play" button and the "Set Motifs" button. The "set Motifs" button is created to give the specialist using this tool the chance to change the motifs that the game requests from the players each time. As a result, when choosing it, a menu appears with all of the saves motifs for the existing levels as shown in Figure 16.

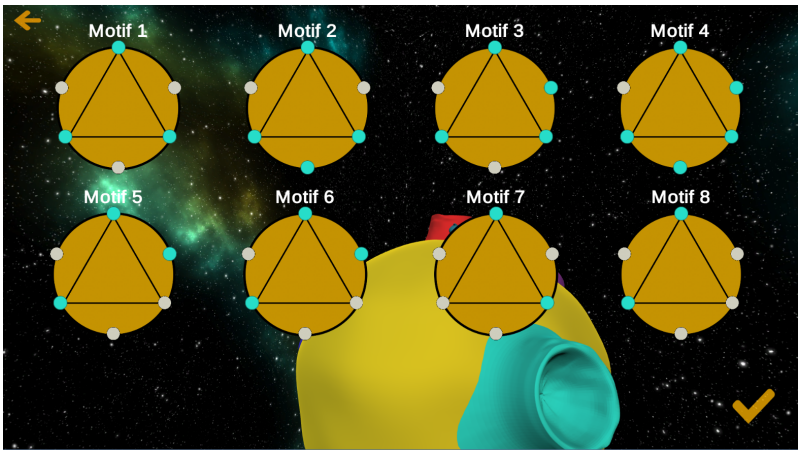


Figure 16: Motif Setting Menu

The motifs are represented in a circle as this book suggests [43] since rhythm is a motif that is periodically repeated in music. Three is also a equilateral triangle inside the circle because it was decided that all of the motifs are going to be of rhythm 3/4. When the player chooses to play, he/her needs to choose between being a new player if the player is trying the game for the first time, or an existing one. If the player is new, the menu that appears requires for the player's name, age

and whether it has ADHD or not. If the player is an existing player, a list of all the players appear, along with the highest level that each one has reached and the player can select an already existing name to resume from a previous game session. The choice to delete an existing player is also available. Afterwards, the player needs to choose whether to play on single Player or Multi Player mode (Figure 17.

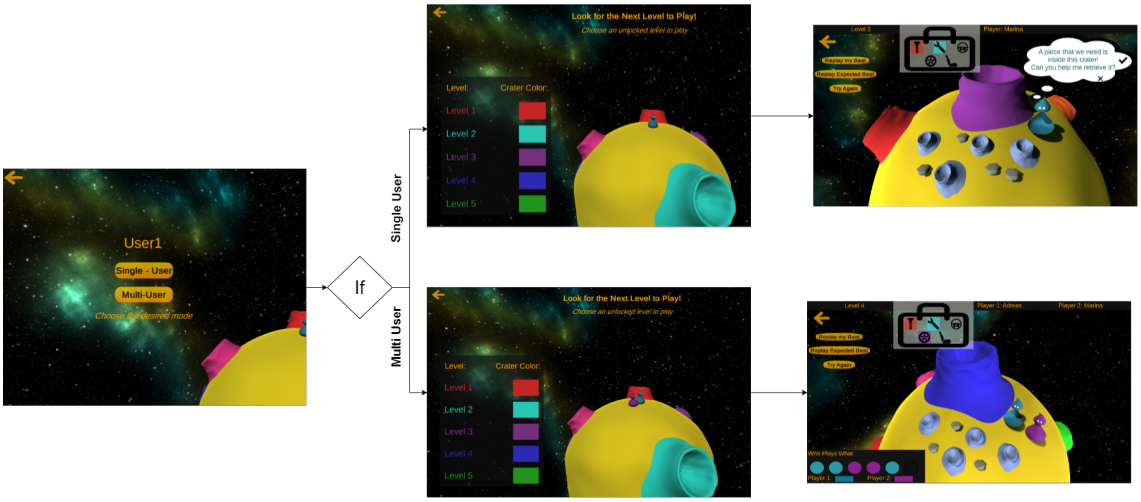


Figure 17: Menu Diagram 2 - Single and Multi User Modes

When that is chosen, the alien is placed on the planet, with a panel that states which level corresponds to which planet by color and as a result, the player needs to walk/hop the alien to the desired crater. The player moves the alien around using the arrows on the keyboard. That happens because it is more interactive for the game to have to search for the levels and creates a sense of adventure and discovery. When the player reaches an active crater, the corresponding level of the game loads (Figure 18. Active crater is every crater that the player has already reached and only one level above his/her achieved level. The choice to just click on the chosen crater is also available.

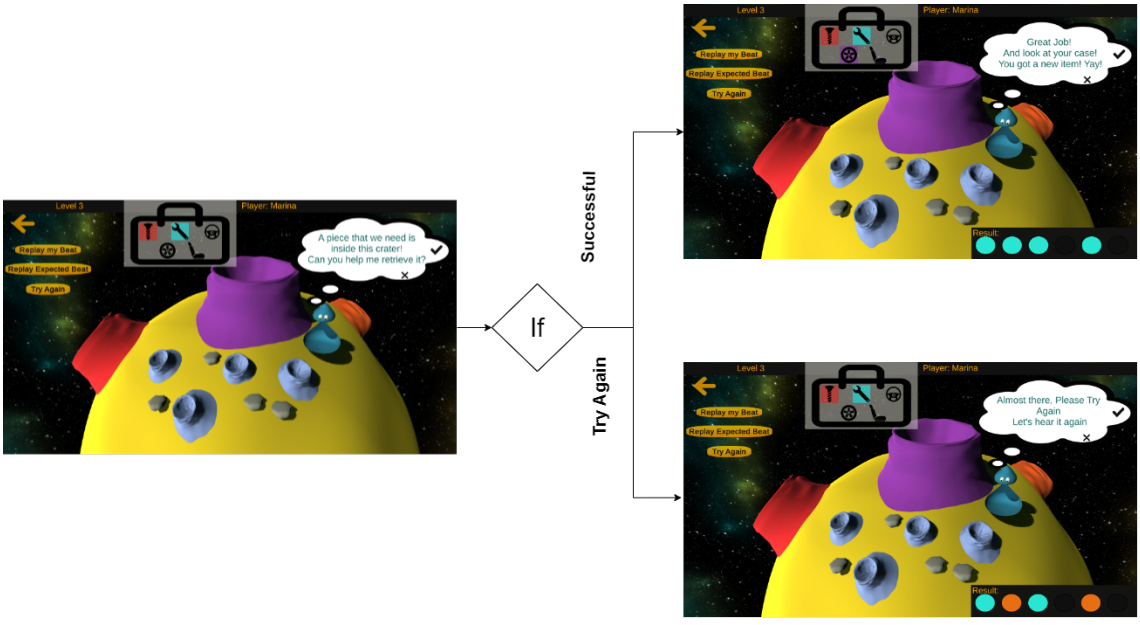


Figure 18: Menu Diagram 3 - Successful or unsuccessful effort

Every new player starts in single-user mode, which is the introductory part of the "ADDventurous Rhythmical Planet". After successful completion of all levels in single-user mode, the new player can move on to multi-user mode. Consequently, all participating players have been already introduced to the environment, the main character and the plot of the game before entering the multi-user mode. Game levels are gradually unlocked as the player progresses. At a certain point, the player can freely select any of the currently unlocked levels to continue.

Additionally, each payer has a suitcase of the acquired items (Figure 19). This

Figure 19: Suitcase of items that indicate the levels passed by the player

suitcase is shown in each level and when the player successfully completes a level a new item lights up inside his/her suitcase. The purpose of the suitcase is to be the reward that the player will receive, which encourages the player to continue into more difficult levels and is also gives a goal for the player to pursue. Regarding the items on the suitcase, each item's lighting is the same as the level's crater's color. That creates a flow through the game and also keeps the player engaged to what is happening every moment. Another important item that appears in multiple stages of the process, is a pop up, which appears close to the main hero, giving instructions, explaining the game, encouraging and guiding the player's next move. That keeps the player engaged and helps avoid frustration (Figure 20).

Figure 20: Level3 Try Again

Regarding the main part of the "ADDventurous Rhythmical Planet", when entering each level, the player sees the main character, the big crater that indicated in which level he is at and a few small craters that will be used to reflect the player's beat the time it is created. Also, a bar is on top of the screen that gives written information regarding the level, on the left and the player's name on the right. Also, the suitcase is placed at the center and top of the screen. There are also a few buttons for returning to the previous menu, replaying the expected beat, replaying

the player's beat and trying again. When the multi-player mode is active, both the names of the players are shown at the top left side of the toolbar and also another panel is shown at the bottom left (Figure 21). This panel shows which part's of the

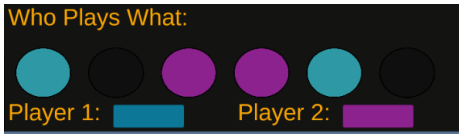


Figure 21: Who Plays What Panel

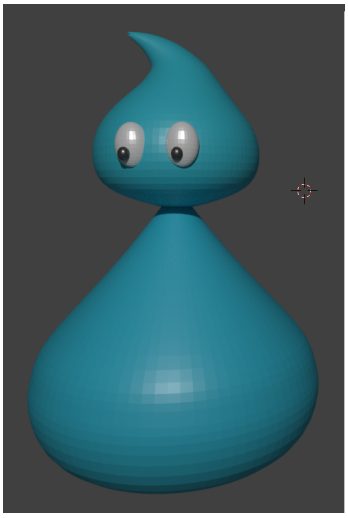
given beat are assigned to which player using color indicators. Also, a pop-up is shown that gives instruction. Once the popup is read, the player hears the beat that he/she is expected to reproduce and at the same time, the small craters light up in sequence in order to give a more audiovisual sense of the beat. Afterwards the player needs to reproduce the given beat by knocking on a drum. At the same time, at the players each drum knock, a small crater lights up and a sound is heard. After the player finishes playing, the game evaluates the player's beat and produces a result line as a visual feedback, showing in color the beats that the player was expected to play (Figure 22). In cyan color are the ones that where considered correct and in orange color the ones that didn't comply with the requirements of a beat being similar to the expected one.

Figure 22: Result Panel

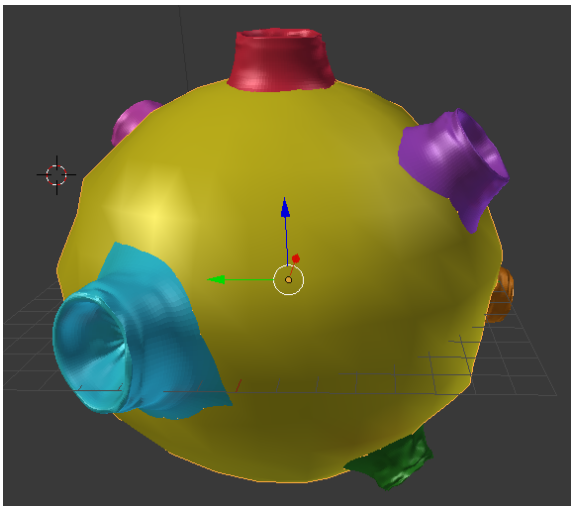
The Game Mechanics related to learning [44] that this game uses are visual. In relation to the learning activity, the player is memorizing concepts, such as rhythm patterns, and in order for this to happen, examples are shown in audiovisual so that the requested pattern is fully understood by the player. The player will be represented by an avatar, and the rules and process of the game will be explained through bubbles of text. The player will receive audiovisual feedback regarding what was right and what was different than the expected motif in each try and positive scoring will be earned each time, as the levels of the game progress.

4.4 3D Models

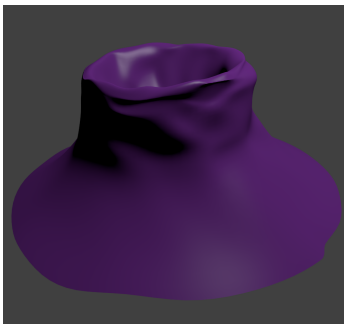
For the purposes of this thesis, the need to create attractive and original characters and objects was imperative. The characters and the environment also needed to be playful, relative to the chosen theme of space, and to make a connection with the players and their age group. The models created are shown in Figure 23.



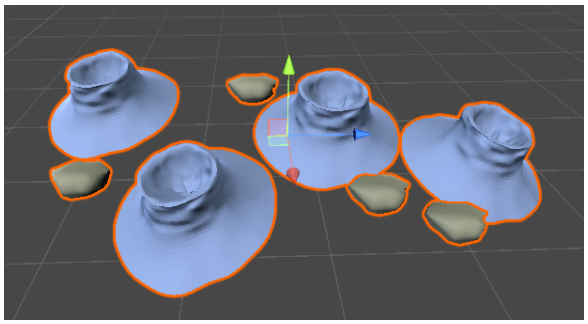
(a) The main Character of the game



(b) The planet of the story and also the main ground for the game



(c) The craters of the planet representing portals for the levels



(d) The small craters with stones representing the beat

Figure 23: The models of the "ADDventurous Rhythmical Planet"

5 Implementation

The work reported in this thesis, is the development of a serious game that is based on musical rhythm as an interface. In the process of making the game more interactive, a musical item was used as input. Afterwards, in relation to programming, the input becomes the given beat and then comes the part where it needs to be compared to the expected beat, and it's correctness to be decided. Finally, an algorithm decides whether this effort is accepted or not, and the player progresses or needs to repeat the level, based on this decision.

5.1 User Input

Starting from the input of the game, there are three ways that this game implemented the process of receiving a beat. Firstly, there is the mouse click, then using a drum,the ESP8266 and a sensor and finally a tin drum and the Makey Makey board.

5.1.1 Mouse Click

This is the basic implementation, which was created for debugging purposes and also for an easy way to play the "ADDventurous Rhythmical Planet" even without the rest of the equipment, using just a computer. Unity offers the implementation of a function that detects when the mouse is clicked and that was used as a starting way to receive the input of the player.

5.1.2 ESP8266 & piezoelectric sensor

To begin with, the means to connect a drum with an ESP8266 and a piezoelectric sensor 24 where by connecting the ESP to the sensor, which was on the membrane of the drum, aiming to catch the vibrations of each knock. An Arduino code was written that using http protocol and making use of the WiFi transmitter that is on that chip was able to connect to a WiFi network and then to the server that was set up into the Unity platform. Also, Using that code, the ESP was giving an ID to the drum connected to it and was keeping time and making sure the ESP didn't go to sleep mode and kept receiving every knock on the drum. At the same time, the ESP was trying to not count the small and probably accidental knocks or the aftermath of a loud knock that was causing a longer curve on the waveform and as a result a false second, or even more knocks. At first, the code kept improving and the false inputs decreased, but after some time and a lot of efforts of trying new sensors, with bigger diameter the results seemed to not get better. The game was receiving false double knocks and even missing some knocks on various occasions. Another problem that we faced was recognizable delays like a one second delay, which is not an acceptable delay when trying to create a rhythmic beat. As a result, the above reasons made it imperative to pursue a more accurate input with no delays, even though we would love some significant positive characteristics such as wireless and real drums, not connected to the computer.

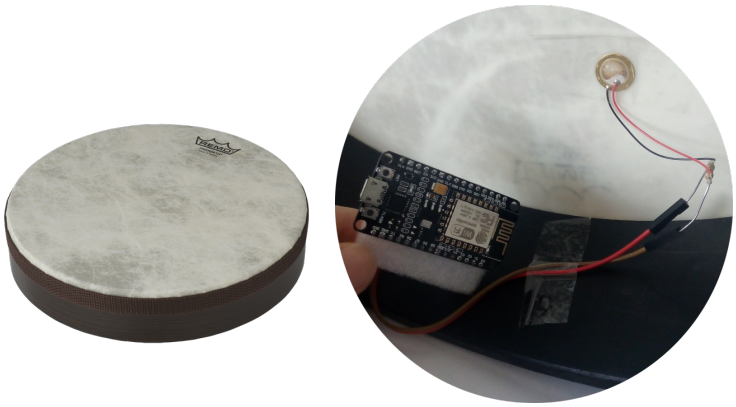


Figure 24: Using a drum and the sensors

5.1.3 Makey Makey Board

In search for a more direct connection with the computer the Makey Makey board came up. As explained above, this board creates an electric circuit between the item connected to the alligator clips and the board. So, the user will be creating an open circuit when placing an alligator clip to one hand, and an alligator clip to a tin, electrically conductive, drum-like surface. As a result, when the player will knock on the drum, the circuit will close and the Makey Makey will send, through USB cable, the signal of a mouse click from the board. Also, the alligator clip that the player needs to hold, since holding a clip, is neither fun, nor practical, a bracelet is used, covered in tin foil and the alligator clip is attached to the bracelet, so it becomes an added playfulness and interest to the game experience and deducts the inconvenience of holding a clip. The use of Makey Makey is shown in Figure 25.

Figure 25: Using Makey Makey

5.2 3D Modeling

An important goal of this project was to create an original and fun game, and as a result, the need to create the 3D models of the game emerged. In order for this to happen,the aforementioned Blender software was used. The models that where created where the Main hero, the alien as shown in Figures 26.

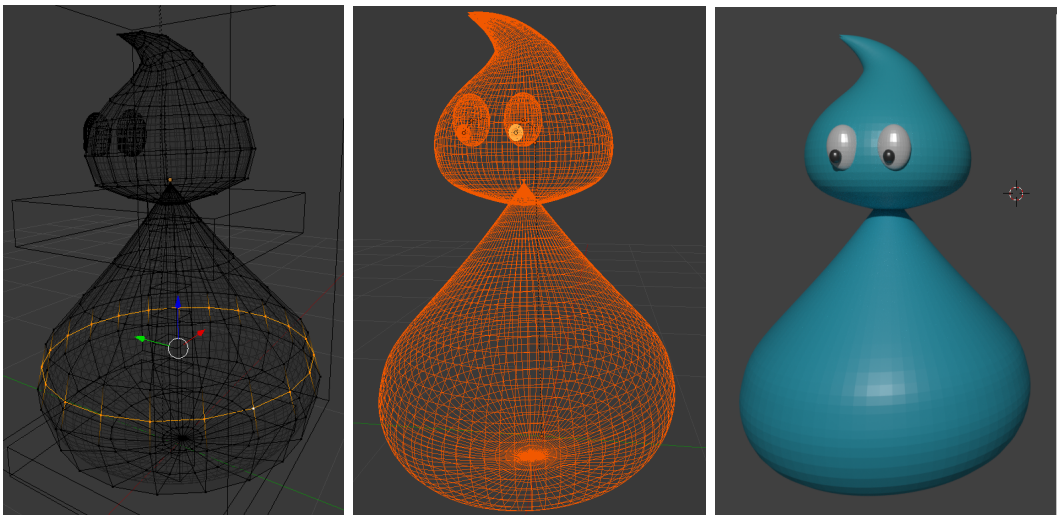


Figure 26: Modelling the main hero

Also, in order for the player to move from one level to another, and not being static, boring, or non engaging, a need to create animation for the movement of

the alien. The main character's movement is a bouncing movement that suits to its appearance. That required more modelling in setting up a skeleton to specify the way the hero will be able to move, as shown in Figure 27. Afterwards, the animation of the main character was set frame by frame as shown in Figure 28.

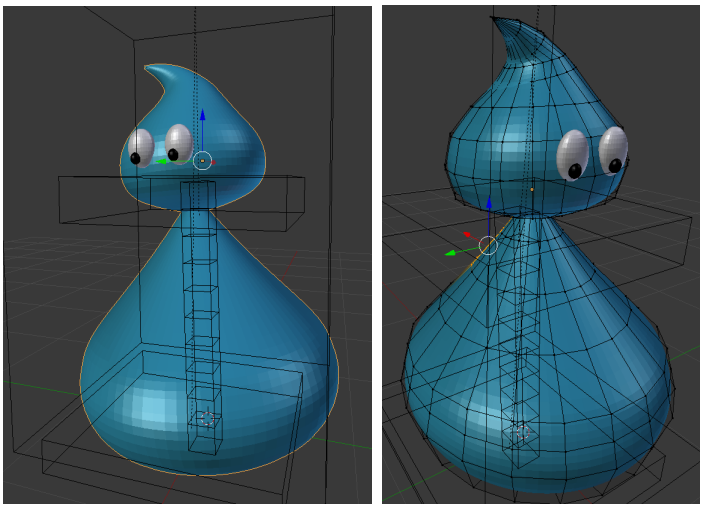


Figure 27: Modelling the main hero's skeleton for animation

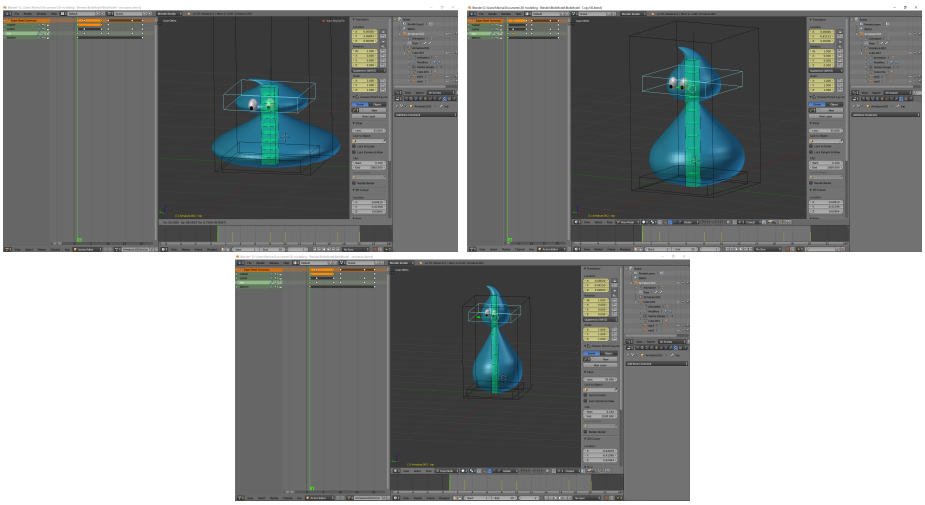


Figure 28: Creating Animation for the main hero

Another 3D model that was created is the main environment of the game, the planet and its craters. It is a planet full of colorful craters who will be the representation of the Levels. The planet modelling can be seen in Figure 29.

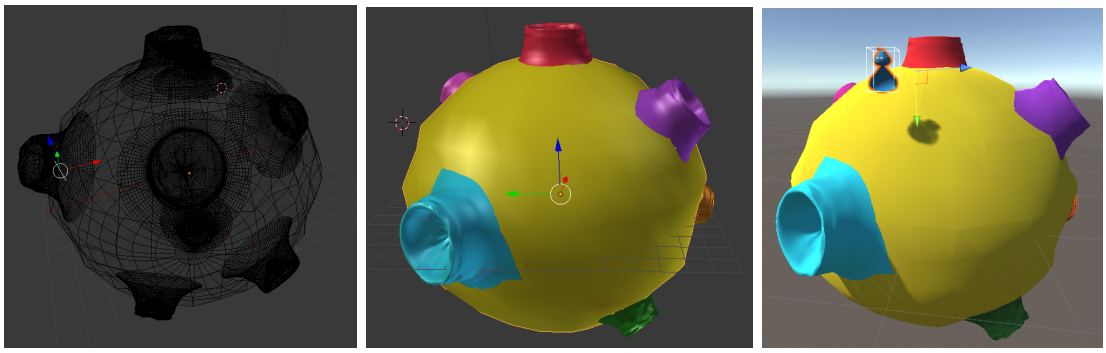


Figure 29: Modeling the Planet of the Game

The craters that were created have a dual purpose. Their first use is to be those large craters shown inf the planet, and the other is to be the small craters that are used while playing in each level to indicate each drum knock. The modelling of the craters is shown in Figure 30 and the second use of the craters in Figure 31.

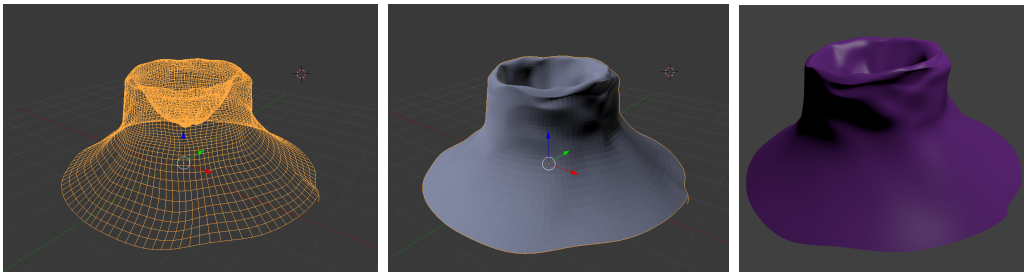


Figure 30: Modeling the Craters of the Game

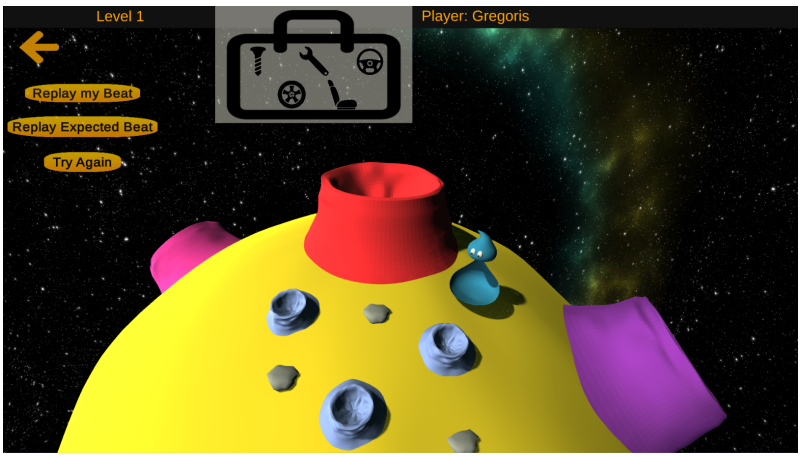


Figure 31: Use of the small craters as indication of the beat

5.3 The Unity project

Moving on to the implementation of the interface and functionality of the game through the Unity platform will be analyzed. There are a few scenes in this game, and they basically are divided to the main scene and the level scenes, which then include the single-player and the multi-player mode.

5.3.1 Main Scene of the Game

The main scene (Figure 32 is the one that covers most of the UIs and implements a "Don't destroy on load" GameObject that manages all the useful information that need to transfer from one scene to another. On that scene the planet and main character have an interactive role.

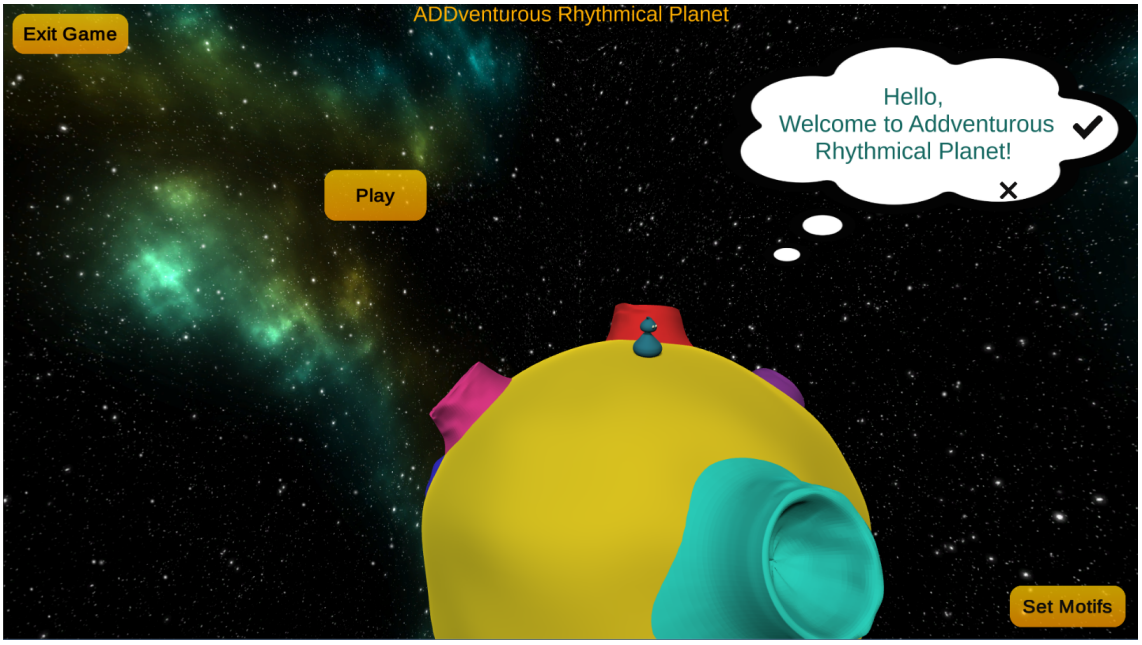


Figure 32: Main Scene of the "ADDventurous Rhythmical Planet"

Firstly, the base of the entire game is the planet itself. This is a 3D model that if order for the planet to be able to move around it, needed to have even the gravity of the platform changed. The planet has a script that creates an attractor like a gravity that attracts specific bodies and the player has a script that gives him the ability to be attracted by the planet. In this stage, the game functions as a first person controller game, and the player can use the arrows on the keyboard to move the alien around the planet. The movement of the alien is not a smooth one as there is an animation created that activated when the player moves. That makes the effect of a bouncing walk to the alien. Also, a clone of the main hero in purple color, exists and appears when the player has chosen to play with another player. So when choosing the level they are walking side by side to their destination, controlled by the first one.

The main objects on the planet, apart from the aliens, are the craters, that function as a portal to the different levels of the "ADDventurous Rhythmical Planet". Each crater has a script that makes the crater glow when a mouse or the player collides with it, and also another script that when the player touches it or the mouse

clicks on it, the crater loads the respective scene, that is, the respective level for the player to play.

Also based on the planet, is a particle system which creates random generated small particles that emit light and blink, and they are scattered around the planet to create the effect of blinking stars. Also there is a Skybox created with galaxy-looking pictures that add a little more light and beauty to the environment.

Moving on to the UI objects of the main scene, there are seven different gameObjects, that each carries different UI objects. Those gameobjects represent the seven different menus of this scene. Those gameObjects are all controlled by their parent MasterCanvas that includes a script that has all these gameObjects in an gameObject List and uses some functions to make sure one of those UIs are shown every time. There is a function there that is called to enable a specific UI and disable any other that is active at that time. Each of those UI Game Objects carry a few button, toggles, panels, text boxes, input boxes that are provided by Unity that serve the functions of creating new players, choosing already existing ones, changing the level's Rhythm motifs, choosing between single player and multi-player and choosing levels, the order of appearance of those menus is explained in detail above.

Specifically, regarding the buttons, each button entails an OnClick function, which in these scenes most times leads to moving to the next menu. As demonstrated in the section User Experience, pushing the buttons "Play" and "New Player", lead to a panel that requests from the player the completion of his/her name, Year of birth and ADHD status. When the player completes that data, he/she has to push the "Ok" button, which in turn calls a function that takes that data and saves them to a new node of type PlayerListNode. Also, this button shows the next menu where the player chooses to play on single-player mode or multi-player mode.

If the player has played the game before, there is already a Node with his/her name. The player chooses the button "Existing player" and as a result, all of the existing players and the level they have reached appear in forms of buttons. Those buttons that represent the different players, are not static buttons. They are generated from a playerButton prefab when this scene is loaded. The data are firstly taken from the PlayerPrefs file in a similar way as the motif Circle's data and then generates as many buttons as the players read. These buttons have a few functionalities. They can be deleted, and as a result they delete the player they represent. When chosen, they move the flow of the game and load another UI, but also they set the active player so that the game can use the data such as the name of the player and the Level that this player has reached. That data will control which craters the player will be able to access when choosing a level to play, as the player is allowed to play all the achieved levels but only one level above the achieved one.

When an existing player is chosen or a new one created, a panel that functions showing colors on one side and levels on the others acts as a guide to which color crater is what level. The reason for this panel is to create some interest and attraction to the player having to look for and go to the next level instead of it just loading on its own. Also it created a flow and a sense of location since the player moves from one part of the planet to the next.

Another button that exists is the "Exit Game" button which quits the entire application. This function happens at the same time as the saving of the players into the PlayerPrefs file after serializing them all in one line of players starting with the word "player" and moving on with the data of the PlayerListNode, each one

divided by a comma and followed by a "/" to divide each player.

The button "Set Motifs" loads a Panel that sets the rhythm motifs. This panel contains eight different motif circles, with an equilateral triangle inside it. Each circle contains six toggles that are placed on the circle so that three of those are on the edges of the triangle and the rest between those three as shown in Figure 33. The panel with all the motif Circles uses a script that sets all those circles with data inside a bigger array of motifs, where each motif is an array of 6 booleans. In order to do that, id calls functions from the script that is on each one of the motif circles. This script takes the data from the PlayerPrefs file, deserializes them and sets the values of each circle. Also, when the tick button is pushed, the same script serializes and saves into the PlayerPrefs all of those data.

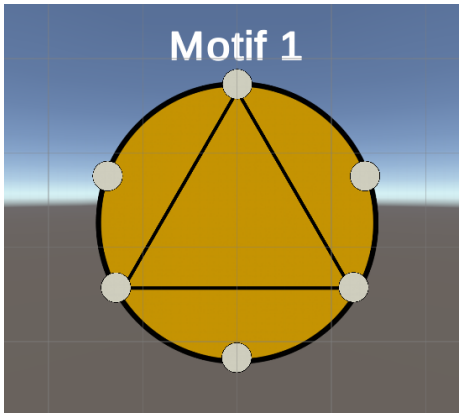


Figure 33: Motif Circle

Finally, an important Object that is found in all the scenes but firstly on the main scene is the instructional pop-up dialogue that is shown in Figure 34. This is also not a static object. It is created on command when it is needed and when it completes its purpose it gets destroyed. The dialogue that is inside the pop-up is different each time depending on where it is created and what has happened. Also, when the pop-up exists, it makes sure that nothing else can happen. That means that the main hero can't move around, and the player cannot play a beat when the pop-up is giving instructions. This popup has two buttons on it. One is the check mark, which indicated that this portion of the dialogue has been read and the next text is shown. The other one is the x mark, which means that the user doesn't need to read it and it destroys it immediately.

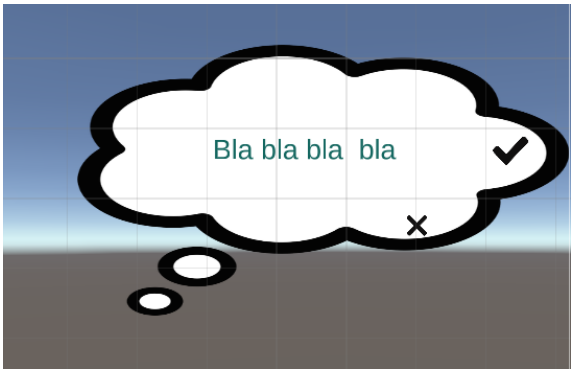


Figure 34: Pop-up dialogue Object

5.3.2 Scenes for Levels 1-5

Moving on to the most important scenes of the "ADDventurous Rhythmical Planet", the scenes of Levels 1 through 5 both for single-player and multi-player mode. They will be analyzed as one since they have the same layout except from the position they are on the planet and some additions at the multi player mode. Those scenes are where most of the main coding has been done and that is why it is important that a few parts of scripting are explained before viewing the different objects on each scene with their functionalities.

To begin with, when the player Chooses and enters an available level, the main thing happening regarding the game play is managing the input of the player's beat. The player starts playing a beat and the input is being received and stored until the player stops playing for 3 continous seconds. A simplified algorithm to visualise this functionality is shown in Figure 35. What this diagram shows is that when reading the player's beat, there is a loop that keeps checking whether the mouse click is pressed, and when it gets clicked, there are three actions happening. Firstly, there is a new knock, with the current time added to the list that holds the player's knocks. Also, there is a sound of a drum played, and finally, there are some small craters at the scene that are the visual representation of the beats. Those craters are all set to a list of gameObjects that every time a knock is played, one by one, the small craters light up using the indication of which number knock is the one played at the KnockList, and as a result the respective crater glows at the respective knock. Because the knocks requested at each levels are not the same, when the small craters are called to be used, the father GameObject of the small craters, checks which craters are enabled and adds only those to the list, so only the existing ones try to glow. Around the small craters are also some stones for beauty purposes and maybe some future purpose as well.

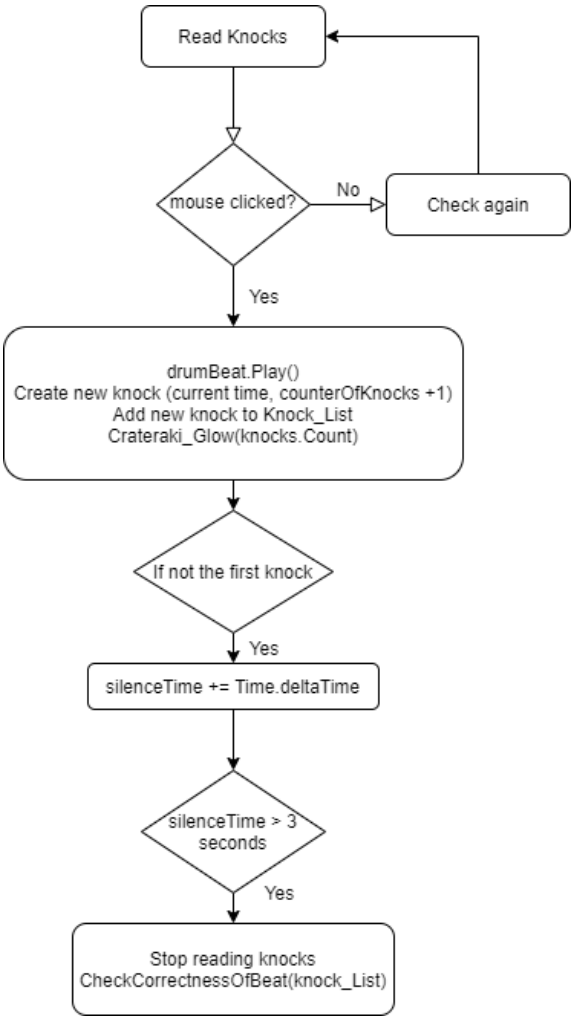


Figure 35: Flow Diagram of the input

Also, after the game stops reading the player's beat, a function that checks whether it fulfills the requirements to be accepted as a correct beat or to ask the player to try again. In this function, each knock gets graded as an accepted beat, a tolerable mistake or an intolerable mistake and also, the missing beats are found and counted. The rules and restrictions as to how these grades are given, was decided by the musician John Papatzanis. The general idea is that it is acceptable if the player skips up to one beat, and it is in fact preferred to not play it than play it wrongfully. Also, when a beat has a small diversion in time, of the level of 0.1 seconds, this is considered an acceptable beat. However, if this window widens and becomes double, there is only one of these errors accepted in order for a beat to be deemed correct. Also, it is not acceptable for the player to play more beats than the given beat. Summarising, the player is allowed to have up to one small time based error, and miss up to one beat, and then the beat can pass the evaluation and be considered correct. When a beat is considered correct, the player receives reward and is let know that he can now move on to the next level to earn more items.

Bellow, there is an more detailed algorithmic representation of the correctness algorithm that compares two beats and concludes whether they are similar enough for the level to be completed (Algorithm 1). This algorithm takes as an input the expected beat and the player's beat. The expected beat is given in the form of

an array whose elements is the positions that the player should have knocked. For this to be understood there needs to be a reminder that all the rhythm motifs are represented in a boolean array of six elements. Those elements are true if the beat should be played and false if the beat shouldn't be.

The main array that this algorithm created is one named PlayerBeatCorrectness. This array's values will be the words "Accepted", "Tolerable" and "Intolerable". Those words indicate in each beat if it is an accepted beat, meaning that the conditions are met, if there was a mistake but it was a tolerable one, which means that it was within the set limits of error, and finally if it is a Intolerable mistake, meaning that the restrictions were not satisfied. The said restrictions are that the player can generally have a delay of 0.1 seconds in all of the beats, but apart from that he/she can have up to one time-based error, and up to one missing beat error.

The algorithm begins by converting the NotesToPlay array into a new array named CorrectTimes, which is an array of the timestamps where the player ideally should have knocked. Afterwards, the player's beat array is transformed so that the first knock is the time zero. Afterwards the algorithm checks for time-based errors. That means that the player's beats are accessed and checked if each of the player's beats has been played within the accepted window, when it was supposed to be played. In each position that that is true, the PlayerBeatCorrectness array take the value "Accepted". In each position that the player played a beat that was expected to be a pause, the PlayerBeatCorrectness array takes the value "Intolerable". This algorithm also checks for the chance that the player has played more than once at the an expected time window, in which case this is an Intolerable knock. Then all the tolerable mistakes are found, those are the ones that are knocked within the double window. To complete this array, there are also the knocks that were completely wrong in time and are deemed "intolerable". During this process a boolean array named CorrectBeatPlayed also takes values. This array take a true value when an element of PlayerBeatCorrectness is "Accepted".

Afterwards the missing beats are counted using that last array. To count those beats, the algorithm searched for a knock that was expected to be played but wasn't. Then the two types of mistakes are counted using the PlayerBeatCorrectness array.

The result of the beat's comparison comes from checking whether the sum of tolerable mistakes with the missing beats is less than one, and there are no intolerable mistakes. In this case only the beat is accepted and the level is complete. In any other case the player needs to try again by repeating the process. In both cases, the function ShowResultPanel is called which makes the result bar appear to the User interface, so that the player can see which beats he/she played correctly and which not.

When a level is completed, the Active player's currentLevel value becomes that level, the level's item inside the case lights up, a pop up appears explaining that to the player and now the next level is available for play. The game returns to choosing another level to play and continues in a similar manner. If however the level isn't passed, the player receives a message that he/she has to try again, the knocklist is cleared and the process of replaying the expected beat, waiting and recording the new one is repeated.

Now that a few basic functionalities are explained, there are a some objects from the main scene that appear in the Level scenes as well. Starting with the single player scenes (Figure 36), they use objects such as the main character, the planet,

Algorithm 1: Beat Correctness algorithm

```
   Input: int[] NotesToPlay, float[] PlayersBeatTimes
   Output: string[] PlayerBeatCorrectness
 1 float beatTime = 1                                  // seconds between two beat
 2 float window = 0.1                                  // window of acceptable error
 3 int[] NotesToPlay       // array with the places where the user should knock
 4 float[] playersBeatTimes                  // array of player's beat timestamps
 5 float[] correctTimes      // only the timestamps where the player should play
   /* Convert NotesToPlay to timestamps:                                        */
 6 CorrectTimes[i] = NotesToPlay[i] * beatTime
   /* Convert PlayedTimes so 1st is equal to zero time                          */
 7 PlayersBeatTimes[i] = PLayersBeatTimes[i] - PlayersBeatTimes[0]
   /* Check time-based errors:                                                  */
 8 string[] PlayerBeatCorrectness
 9 bool[] correctBeatPlayed                  // array with the results of each beat
10 for each PT in playersBeatTimes do
11     for each CT in CorrectTimes do
12         if PT between += window of CT then
13             if !CorrectBeatPlayed[CT] then
14                 CorrectBeatPlayed[CT] = true
15                 PlayerBeatCorrectness[PT] = "Accepted"
16             else
17                 PlayerBeatCorrectness[PT]="Intolerable"
18     for each CT in CorrectTimes do
19         if PT between +- window*2 of CT and
             PlayerBeatCorrectness[PT]!="Accepted" then
20             if !CorrectBeatPlayed[CT] then
21                 PlayerBeatCorrectness[PT]="Tolerable"
22             else
23                 PlayerBeatCorrectness[PT]="Intolerable"
24         else if PlayerBeatCorrectness[PT]!="Accepted" then
25             PlayerBeatCorrectness[PT]="Intolerable"
   /* Check missing beats errors                                                */
26 int missingBeats=0                  // Number of beats that the player missed
27 for each CT in CorrectTimes do
28     if CorrectBeatPlayed[CT]==false then
29         missingBeats++
30         if CorrectBeatPlayed[CT+1]==false AND NotesToPlay[CT+1]-
             NotesToPlay[CT]==1 then
31             i++
32 int tolerableMistakes = Count(PlayerBeatCorrectness == "Tolerable")
33 int intolerableMistakes = Count(PlayerBeatCorrectness == "Intolerable")
34 if tolerableMistakes + missingBeats ≤ 1 AND intolerableMistakes == 0
    then
35     AcceptedBeat()
36 else
37     TryAgain()
38 ShowResultPanel(CorrectBeatPlayed)
```

the craters and pop-ups, but with different dialogue content. Adding to that, there is a thin black panel at the top of the scene, informing of the Level the user is at, and the name of the player or players. That data are also not static, meaning that they are retrieved and written there every time a level scene is loaded. The Level number is the number of the build index of each scene and the Player's name is retrieved from the data of the ActivePlayer1 PlayerListNode. That is a PlayerListNode that is set every time a user created or chooses an existing player.

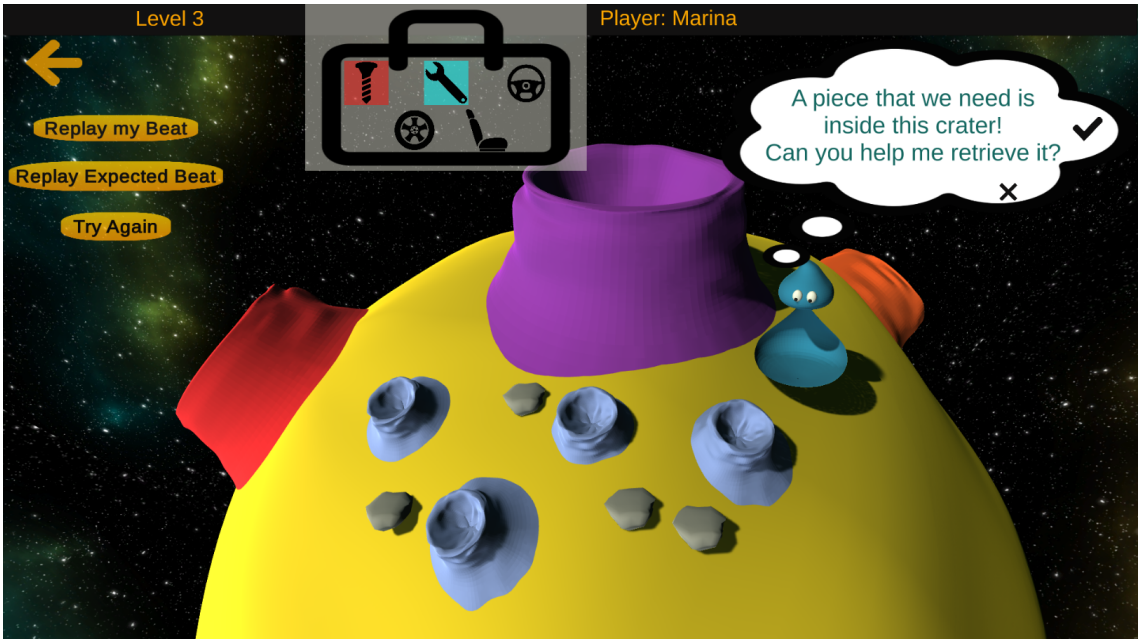


Figure 36: Single Player Scene

A new object that exists in this level is the suitcase. This object basically shows the progress of the player and contains the main reward that the player receives when a level is completed. In more detail, when the level scene loads, depending on which level is loading, it means that the player has already acquired the items of the previous levels and as a result, the suitcase shows all the previous level items glowing in their respective colors. That happens using a script on the suitcase that enables a background image at each item. All the items in the suitcase are in a list and depending on the level, the function enables all the backgrounds up to the previous number of the level. Furthermore, when the player completes the current level, the new item representing that level also lights up that moment.

Also there are the buttons that replay the players' rhythm and the expected beat, and the "Try Again" Button. Each of those buttons call a specific function that performs a series of actions. Starting with the "Replay My beat" button (diagram in Figure 37, this button calls a recursive function which uses the list with the player's beat and finds the time difference between the beat meant be played and the next, plays a drum sound and makes the corresponding small crater glow, and waits for as many seconds as the time difference to play the next sound, and the same again for the next beat until reaching the end of the list. The "Replay Expected beat" button also calls a function that uses a similar way to reproduce the correct rhythm. The difference is that the correct beats are saved in a different format than the player's. This format is a boolean array, and there is a variable that indicated the speed of

the beat, and so this functions checks if the current beat is supposed to be played, and if it is, then the sound and glow of the crater is made, and then the functions wait for the an amount of seconds indicated by the speed variable and checks again in a loop for the next value of the array.

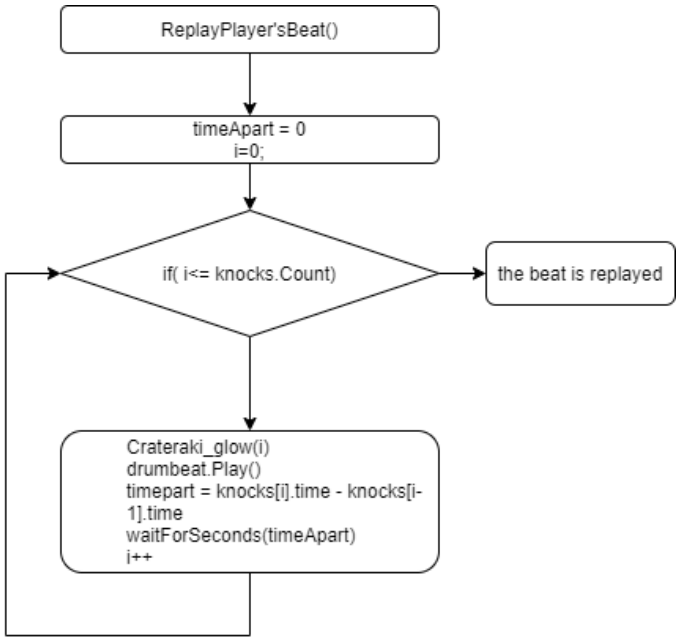


Figure 37: Flow Diagram of the Algorithm for Replaying the player's beat

As to the Try Again button, this is a process that basically clears the data already set regarding the player's list and resets its reading indicators so the game can read again for a new beat. Also, it calls for a pop up dialogue to appear with two alternating versions that asks the player to try playing the beat again and listen to the expected beat again.

A very important object with interesting functionality in these scenes is the Result Panel shown at the bottom right of the scene. This panel is shown only after the player has finished playing his/her beat. When that happens, the correctness of that beat is judged by the algorithm mentioned above, and the result is shown on that panel. This is a black rectangle panel with 6 circles, like the motif Circles analyzed above at the motif Setting menu, that have three different colors, the color cyan for when that knock was correctly played, an orange color for when the knock was mistaken and a black color so that it almost disappears to the black background, when that beat was not supposed to be played. Figure 38 gives a glimpse of what this panel might look like. The correctness algorithm creates an array of six booleans giving exactly that information that this panel needs to show. As a result, when the correctness evaluation is complete, the panel appears, gets that array and uses it to set the values of each of its children circles' background colors.

(a) One beat was wrong, need to try again

(b) A few mistakes, need to try again

(c) everything was correct, moving on to the next level

Figure 38: The result panel with different results

When the player moves to the multi-player mode, he/she chooses another player to play with. In this mode the two players are going to collaborate to create one beat. Figure 39 shows the scene that the players face when on this mode.

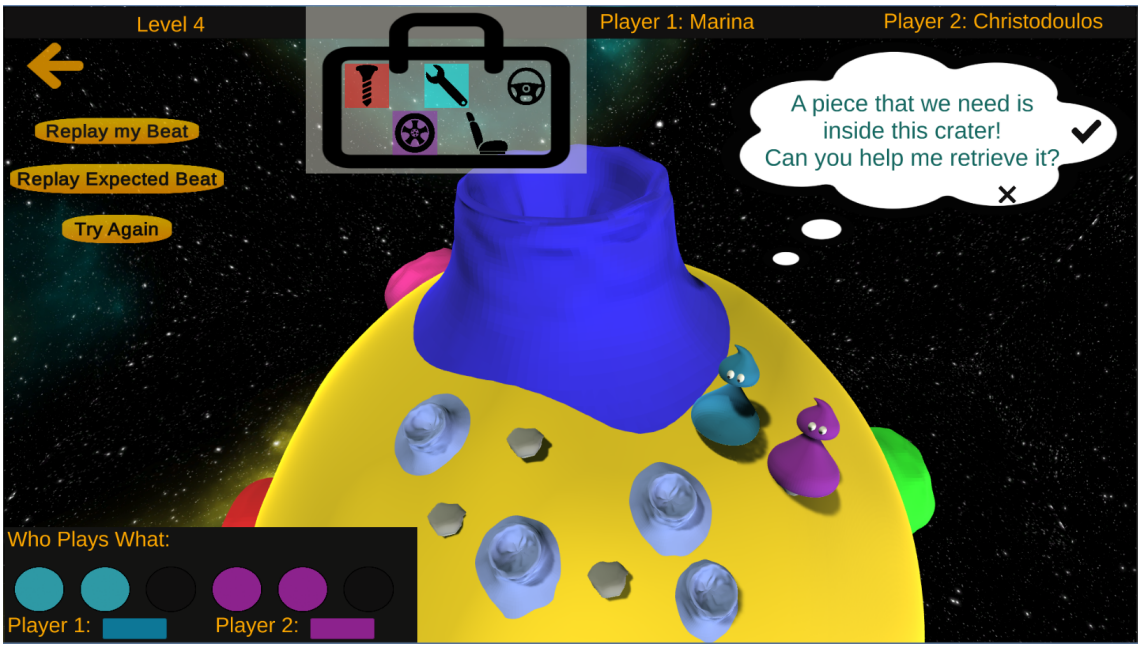


Figure 39: Multi Player Scene

In this scene, there are two names set as ActivePlayer 1 and ActivePlayer2, and as a result, two names appear on that the black panel at the top with the indication "Player 1" and "Player 2", adding to the Level indication. All the buttons existing to single-player mode remain. Also, the planet, craters and small craters with rocks, the pop ups and the result bar remain as well. A new alien same with the main hero but in purple color is shown next to the former one. Apart from that, the new and vital object of this scene is a new panel at the bottom left of the scene. This is the "Who Plays What" panel, which is a black rectangle panel similar to the result panel, but this one as the name indicated show which beats of the motif should

the player 1 play, and which the player 2. To show this, firstly there is written indication at the bottom of the panel showing that the player 1 is symbolized with a petrol color and player two with a purple color. Other than the appearance of this panel, there is an algorithm used to decide which beats should be played by which player in the most possible and logical way, using also the guidelines the musician Mr Papatzanis gave to us. The way this decision is made is that the algorithm starts by assigning the first color in to the first beat that should be played, and then it assigns the same color if the ones next to it should also be played without any pauses. When a pause gets in the way the color that will be assigned next changes, and the same continues until the loop of the algorithm has assigned a color to all the beats that should be played.

5.3.3 Implementations that are not on the final game

Additionally, a save system was implemented aiming to be able to create a csv file with all the players' data. The way this happens is in a similar way that the players are saved at the playerPref files. A serialization happens using comas to separate the data of each player and saving a file named "Players.csv" to the persistentDataPath of the computer in a folder named "Saves". To begin with, this happens every time the game closes. Then, the path is checked to see if such a file exists and if it does, this file is replaced by a new one. Into this new file, a string is written that has written in each line an entry of a player. The way it reads the data from the csv file is that it deserializes them in the opposite way and saves them to a PlayersKnockList. However, the second part of the reading process wasn't functioning reliably and also that data isn't used in the final version of the game because it was realized that that data offered no researching purpose so far. However all the scripting files are kept in the project because it is possible that they are going to be useful in a future version of the game, and the "Players.csv" file is also created when closing the application. Because of this non reliability of the reading process, the method implemented was the one using the PlayerPrefs file, as explained above.

Another implementation that doesn't exist in the final build of the game was a progress bar (Figure 40), which would be used if the result of the comparison between the rhythms was metric. This progress bar when called, it appeared and filled up to the percentage given to its function, using animation for the filling up. Nonetheless, the comparing method ended up having a completely different representation, so this progress bar wasn't used.

(a) Result: 15% correctness

(b) Result: 70% correctness

(c) Result: 100% correctness

Figure 40: The progress bar with percentages as results

6 Pilot Evaluation - First impressions on the tool

A pilot Evaluation of the tool that was created took place, and used two types of questionnaires, one referring to children of 8-12 years old and the other to educators. The aim was to see whether the game is perceptible from the user, whether it looks promising on promoting collaboration and communication and to hear any remarks aiming to improve the overall look and functionality of the "ADDventurous Rhythmical Planet". For this purpose an open-end, qualitative analysis was used.

6.1 Evaluation metrics

For the purpose of this analysis, two questionnaires were created. The questions are divided in four parts. The first part refers to the first impression, the second to the experience of the user while playing the game, the third about the difficulties that where faced and the fourth one was about the general impressions from the game. The questionnaires were filled out by the researcher and were referring to the educators and the children. Both of them can be found in the appendix Chapter.

6.1.1 Children's questionnaires

Starting with the Children's questionnaires, in the beginning, there are some demographic elements such as the sample number, the date that the questionnaire was filled out, the year of the user's birth, the gender, whether there is diagnosis of ADHD, if there is knowledge of the English language, and pre-existing knowledge of music. These data is needed for the anonymity of the users while acquiring all the necessary information.

Moving on to the first part of the questions, which refers to the first impressions during the first encounter with the game. In detail, the questions aim to record the firs impression of the user regarding the environment of the game and the main character and whether there was need for further instructions when moving around the environment. At the second part, the users experience is described. The questions record degree of difficulty of the single player is given in the user's opinion each time and the level that the user reached. Also, again, there was a question about whether further guidance was needed for the user to proceed through the levels.The third and fourth part require that the researcher records the difficulties faced and the general image that the user is left with after playing the game.

6.1.2 Educators' questionnaires

In the educator's questionnaires, the demographic elements needed are the sample number, the date that the questionnaire was filled out and whether the educator was a special education teacher or not. Those elements are significantly fewer than the children's because the gender, the age and the musical and English language knowledge of the participant are of limited significance when referring to adults. These questionnaires similarly to the children's questionnaire is divided into four parts.

The first part refers to the first impressions. The opinion of the educators is requested before playing the game, regarding the environment of the game. Additionally, they are asked if they think a child with ADHD would be attracted to

the "ADDventurous Rhythmical Planet", and if that game could, based on their experience, promote collaboration. Moving on to the second part, the educator has already played the game and the researcher records the educator's opinion about improvements and the level of difficulty of the game. The third part, asks the educator for a prediction as to which difficulties might the children face during the game and if the multi-player part of the game would promote collaboration. Finally, the questionnaire finishes with an open question about the general impressions of the educator about the game that he/she just played.

It is important to take into consideration that these questionnaires were created specifically for the use of this pilot research. The reason that the questions are open-end is because we were interested in the opinions of the participants. Those opinions were meant to be personal feedback for the researcher.

6.2 Children 8-12 years old - application of the game

The first user was a 9 years old male, diagnosed with ADHD among other disorders, and with no knowledge of the English language and no musical knowledge. The first impression was very positive. He was very excited with the story, the environment of the game, and he really liked the space and the main hero, the alien. For the user, the single-play mode, was of medium difficulty, mainly the pauses between the beats appeared to be difficult, especially the double pauses. The user was very impatient to play and made a lot of mistakes due to that. Also a lot of guidance was needed from the researcher mainly due to the mistakes and lack of knowledge in English. The user completed Levels 1, 2 and 3, and did not reach 4 and 5 due to technical difficulties. The difficulties were mainly on the Makey Makey, probably some crocodile clip was not properly connected. At the final question, whether he liked the game, he responded that he really liked it and would like to play it again.

The second user was an 11 year old male, diagnosed with ADHD, with excellent knowledge of English and no previous musical knowledge. He was very curious to find out what the game is about and what he has to do to play. Also he needed no instructions on how to navigate to the environment. He was very fond of the main character, liked the fact that he is bouncing around, and thought that he is very sweet. He too was impatient, when he had to try and play the beat again, and was trying to play his part before the game replayed the expected beat. He didn't need any guidance in playing the game either. This user finished all 5 Levels of the single-player mode and played the multi-player with the researcher as the second player. He completes all 5 levels of it too and said that it would be great if he could play it with friends! In regard to the difficulties of the game, the user had a difficulty with the pauses at the first two levels. But very soon he understood the logic of rhythm and was very successful at the rest of the levels. In fact, by the last level he could pass the level in only one effort, while at the first levels he needed 3-4 tries. He remarked that he thought the game was very good, that he liked the tin drum more than using a button on the keyboard or the mouse, and that it was very cool. Also he suggested that there would be additional pop ups when arriving at a crater that you cannot currently use and when explaining the logic of the multi-player mode.

The third user was a 9 year old male without ADHD. Also he had some knowl-

edge of English and he knew how to play the violin. When the game starts, the user says that he likes the game ans that he likes moving around using the alien main hero. Instructions the instructions on the game are given verbally to the player because the knowledge of English is poor. The user finds the main character fun and attractive. For this user the difficulty of the game seems easy to medium, as he gets the correct rhythm with the first or second try. The researcher needed to give a few more instructions while playing the game so that the game became more clear to the user. This user completed all 5 Levels of single-player mode and played the multi player mode with user 4 and completed it all 5 Levels of it too. The player did not record any difficulties and thought that it was a smooth game process. He finally reported liking and in fact being impressed with the game ans also with the tin drum that was used, and the objects that he would get in the alien's suitcase when passing each level. Finally, he asked where he would find the game to download it so he could play it at home with his friends.

The fourth user was a 10 year old female without ADHD. She had some knowledge of English and some knowledge of playing the guitar. When the game starts, the user remarks that it seems awesome. A few instructions are given from the researcher and the girl comments on liking the craters a lot and the main character as well. At the single-user mode, she had no difficulty and completed almost each level at the first try. The user completes all 5 levels of the single-player mode and played the multi-player mode with user 3, which they completed as well. The girl was very happy with the game and liked everything she saw. She mentioned liking particularly the multi-player mode and that she would love to play it with her friend who likes to sing. She commented on enjoying the musical part of the game as well.

6.3 Educators - application of the game

The first educator was a special education teacher. This teacher found the environment of the game particularly interesting and attractive and thought that it is very likely for a child to be interested in exploring it. Specifically, this educator thought that a child with ADHD would definitely be interested to spend time with it especially due to its space theme. He/She thought that collaboration could be promoted, in particular because the game asks from the users to synchronize rhythmically in order to create a melody, which is attractive and interesting. The game was deemed of medium difficulty, and the teacher thought that if the child had been formerly in touch with a drum or maracas for example, in the school environment, the entire effort would be better accommodated. As an improvement to the game, the choice of changing the language to Greek was suggested, because most children of ache 8-10 are not very familiar with the English language. Also, regarding the possible difficulties, he/she thought that the children might be impatient, and have a hard time to carry out the pauses expected to complete the levels. Also, regarding the multi-player mode, his/her opinion was that this game would be a useful tool for children with ADHD, because they can learn how to wait for their turn, and cooperate with their teammate.. or else they will both lose! Finally, the game seemed attractive to him/her and suggested that it would be an interesting tool to be used at an occupational therapy framework aiming at cooperation, but also at a school environment as a decompression tool or as reward.

The second educator was not a special education teacher. This participan's first impression was that the interface was very colorful and attractive. Also thought that the hopping main hero would be very attractive to children with ADHD. Also, thought that a game that asks players to create a part of music together could really promote collaboration. When the participant tried playing the game thought that it was of medium difficulty and recommended that the different players could have different types of instruments. After finishing playing the game, the teacher commented that it could be more apparent that the pop ups where needed to be read for the user to understand how to play the game, and so they should be constricted to reading them before pressing any other button. Also, about the game promoting collaboration, the teacher thought that it could easily make children to want to collaborate, since they will want to move on to the game and therefore they will have to play together to progress in the game. In general this teacher considered the game to be a very interesting and good game and mentioned that would definitely play with it but also use it in the classroom.

The third educator was a special education teacher. Starting with the environment, the participant thought that it was an attractive environment. Also, considering children with ADHD, the educator found the general design of the environment and the colors used quite perfect, since the planet with all its bright colors attracts the attention and the dark space background gives a feeling of space while sending the attention to the center of the scene. Also, considered the game's description to be promising in promoting collaboration. The game was deemed to be of medium difficulty. Suggestions regarding improvement of the game were made mainly regarding the implementation of a Greek menu, also the participant would like to see the main hero from up close at some point and would recommend that there would be an op-

tion in changing the sounds of the game. No possible difficulties were noticed. After playing the game, this participant felt that this game definitely promoted collaboration, since achieving the creation of the expected music could only happen if both the players are correct, and as a result collaborations becomes a precondition for victory which will certainly motivate the players to want to collaborate. After the game, the general impressions were very positive. More specifically the environment, the colors of the planet, and the space all seemed very beautiful choices and will attract the attention of the players. And finally, the participant thought that the physical touch that the multi-player mode requires will also promote collaboration and better communication.

The fourth participant was a teacher of general education. Starting with the environment, the chosen theme of space is what attracted his/her attention, which he/she considered to be an participant that would interest children with ADHD, and thought that the entire environment would attract is designed in a way that would attract their attention. This teacher thought that the way this game tried to promote collaboration is very creative and innovative and would have great results. After playing the game, he/she considered the game to be of medium to hard difficulty. Furthermore, this participant thought that this game could be improved by having a Greek menu option, more animation from the character when making mistakes and more levels in the game. Also, the suggestion for an animated introduction to the game was made. Also, the only difficulties this participant considered the children to face were the lack of knowledge of the English language and the possible impatience for them to wait for their turn to play. Regarding the multi-player mode, the teacher thought that this mode promoted collaborations through touch and also it creates a situations where two players are connected and feel like a team, the one player needs to help the other in order for them to complete each level and also they are made to each wait for their turn. Conclusively, the participant thought that the game has an engaging environment and that it is particularly interactive and gives the children an introduction to the sense of rhythm as well.

6.4 Questionnaires Results

6.4.1 Children's Questionnaires Results

As it can be concluded from the children's responses, in general, they liked playing the game and in regard to collaboration, it seemed to promote the team spirit. In detail, from the first category of questions, the conclusion is that the environment is very attractive for the children. Furthermore, they seemed to like the fact that the game is placed in space and they adored the bouncy effect of the player. From the second category of questions, the degree of difficulty was judged to be of level and the users in general needed some guidance mainly due to the lack of knowledge of English.

The majority of the users completed all five levels of the game's single-player mode, except from one player who reached to level three due to technical difficulties. Those who where given the opportunity to play the multi-player mode, completed all five levels of this mode too. At the third category of questions, the main difficulties that appeared were concerning the pauses of the requested rhythms. Finally, at the fourth category of questions, the children were really excited to play this game and they particularly enjoyed the multi-player mode. It's interesting to refer that all of them wished to share the game with a friend as part of a joint activity and not as part of a competitive process. From these facts one may conclude that playing this game was a very pleasant experience for the children. Finally, the game seems to be particularly engaging for a child of age 8-12 years old as there were no drop out examples in the users, meaning that no child got tired or bored and stopped playing.

Taking into consideration that two out of four users have been diagnosed with ADHD, their reactions should be especially noted. Both of them were fascinated by the environment and the process of the game, and in the beginning they seemed quite impatient. Despite that, they waited patiently for the researchers instructions and they complied easily to the rules and tasks of the game. Unfortunately, it wasn't possible for neither of them to play the multi-player mode with a peer, but it was something they really sought to do, so the researcher volunteered and played with one of them. He got pretty engaged to the game and excited about the rewards he got into hid suitcase, so he stayed focused for twenty minutes straight. With the other player, some technical difficulties appeared, so the process had to stop at the third level of the single player mode due to lack of time. All things considered, this was a successful trial that demonstrated that a child with ADHD would be excited enough to play this game that he/she would stay engaged on it for as long as it takes.

6.4.2 Educators' Questionnaires Results

Taking into account all the above, the educators' opinions were particularly positive towards the game. During the first contact with the game, they found the environment interesting and engaging and expected that children with ADHD would also be attracted to it, due to the interesting space theme and colorful planet. On top of that, they anticipated that this game could promote collaboration, since its asking children to create melody together and that seems like an interesting task. Moving on to the second category of questions, the difficulty of the game was also deemed of medium scale by the educators. The suggestions they made in regard to

the improvement of the game were to create a Greek menu as well, give the users the opportunity to choose the sound of their drum and also have more instructional pop ups so that the children need no further instructions from the researcher.

At the third category of questions, they assumed that the basic difficulties the children would face would be the language and the pauses that the rhythm requests. All the participants believed that this game promotes collaboration because it motivates the players to cooperate because they will want to progress in the game. Collaborating would be the only way to complete the game and also the way the game is structured could help the children to learn how to wait for their turn. In the last category of questions, the educators expressed their enthusiasm for the game and their willingness to use it on children with ADHD individually and as a part of the learning process in a classroom. Also they unanimously considered the environment to be very impressive, engaging and on point regarding the target group.

7 Conclusion & Future Work

7.1 Conclusion

The sector of serious games for children, has appeared the recent years, with numerous applications giving the researchers the opportunities to create extremely helpful tools and introduce playfulness into the process of education. During the recent decades, the number of children diagnosed with ADHD is rapidly rising. These children are facing a set of difficulties that could have been managed if given the required attention and care in order so as to become fully functional and accepted by their peers. All the above were the inspiration for this thesis.

The "ADDventurous Rhythmical Planet" game presented in this thesis aims to offer its players the capability to improve their social skills and learn to cooperate with other children. It can be used in typical children as well, but it mainly focused on children diagnosed with ADHD, since they appear to face more often social discrimination and loneliness. This game uses rhythm as the main tool to achieve that. From the present research it appeared that there is a limited amount of serious games aiming to help children with ADHD so far. Adding to that, it appears that for the first time in literature, a game is created for children with ADHD that aims to improve the psychosocial issues that they are facing using Rhythm. More specifically it can bolster collaboration, using rhythm as the medium to achieve that.

In more details, the game using a story, a playful main character and engaging environment, attracts the player to the game. Afterwards, the player gets introduced to the gameplay while logging its data and choosing a level to play. The player starts with the single-player mode. In this mode, the player becomes familiar with the functionality of the game and the main tools such as the rhythm, the tin drum and the bracelet and practices. With the intention to ensure that the player stays focused, after completing each level he/she gets a reward in the shape of a spaceship part or tool, that is different each time.

When the single-player mode is completed, the player chooses another player to collaborate with, and moves on to the multi-player mode. During this mode, the players need to cooperate and each wait for their turns for the purpose of completing the level and acquiring more tools and parts aiming to complete the story and finish the game. The two players interact in a level of collaboration, as they have to cooperate in order to play the rhythm requested. This will help a child with ADHD to learn not to interrupt his/her peers and wait for his/her turn. Additionally, it gives the opportunity to the two players to communicate and help each other correct their mistakes.

After a pilot testing with educators and children, typical and diagnosed with ADHD, the first impression and thoughts are given. The "Addventurous Rhythmical Planet" is expected to perform particularly well in keeping the players engaged and bolstering collaboration. The children were very excited to play and the educators seemed particularly interested in applying this serious game to a larger sample group as it seemed to be predicting great results. All in all, the trial of this game gave encouraging results suggesting the expansion of the game in levels.

7.2 Future Work

7.2.1 Further Implementation

Having concluded that this game, the "ADDventurous Rhythmical Planet", could be beneficial for children with ADHD it is deemed appropriate and fitting that further implementation would take place. Also, deriving from suggestions from the educators and children that tried the "ADDventurous Rhythmical Planet", and other associates, some suggestions regarding the visuals and audio of the game where created, and also some regarding further functionality implementations.

Regarding the Welcoming scene of the game, there where a few suggestions regarding the visuals and audio. The idea was that is could be clearer to the player which crater was allowed to be entered. The idea is that when the player will try to enter a level that is not yet available to him/her, the crater will show an indication on top of it that will say "Sorry, you haven't unlocked this crater yet". And Also that when the player will be moving around, he would need to press on the planet, or to press enter to enter the respective level so that there will be no false level entering due to passing by a crater to get to another. Also, in the level scenes, when completing the level, more animation and effects would be interesting to be implemented. The main hero could be having face expressions and animation to show that it is happy, and also, the craters could be having an effect such as an explosion effect making the item to fly out of the crater and into the suitcase.

Furthermore, the game could be more customizable regarding the difficulty of the motifs and the speed of the beats. That means that the motifs could be categorized into easy, moderate and difficult and also the speed of the beats, and they could be changed manually from the players or the instructors. That would help the player not to give up or feel frustrated, so he/she would keep playing. There could also be a different instrument sounds for each player to choose. That way each player would have a more personalized profile. Also, when playing together in multi-player, the result would sound more interesting.

Finally, the original architecture of the game, using ESP8266 with a sensor could be examined in more detail. The issues faced with this microchip could be resolved, and maybe trying other types of sensors could result in more accurate readings of the knocks. This would mean that a wireless version of the game could become available.

7.2.2 Extensive Evaluation

There are measurable tools that can calculate and evaluate the gamified intervention as a therapeutic tool. The assessment tools are the history of play from each player, including the time it took for each stage to be completed, how long each session lasted, and monitoring progress in order to assess the rate of improvement in the game [45].

In order to evaluate the "ADDventurous Rhythmical Planet", multiple groups of children will test the game and psychosocial evaluation will take place by special education teachers, who will try to see whether their social skills and interactions are evolving better than before as the time passes.The Strengths and Difficulties Questionnaire (SDQ) [46] will be used for this purpose. SDQ is a brief behavioural screening questionnaire for children 3-16 years old. It exists in several versions to

meet the needs of researchers, clinicians and educationalists.

The goal is that as the game's development progresses, it will be possible to monitor the progress of the player and dynamically adjust the difficulty level. Such dynamic adjustments could even include the visual style as well as environment and difficulty of the game in order to match individual player's needs according to his/her diagnosis. Based on detailed data logs, parents and specialists can be informed of the ongoing progress of each player.

7.2.3 Alternative environments for the Game to take place

The game aims to not only help children with ADHD but also provide an educational tool to the specialists that work with ADHD, as well as the teachers, their classmates and the parents. The collaborative aspects of the game as well as the fact that it involves multiple senses (visual, auditory, motor) are holistically benefiting the social cohesion of a class, creating social bonds between children of potentially different abilities and background.

The "ADDventurous Rhythmical Planet" game can be played in class by the students and even the teacher. The goal is to improve the social skills of the main player who could be a child diagnosed with ADHD but also enhance the child's social integration and cohesion of the class. The technological challenges presented when such a drum game is integrated in a school class is that it should be possible for the game to be simultaneously played by more than 15 players in an elementary school. The game could be easily integrated as part of the music course of an elementary school. However, other options are also possible such as the introduction of this game as part of classroom management activities to promote mutual understanding and cooperation in mixed classes with children with ADHD.

This game will be used within the context of the pilot activities of the rhythm4inclusion project (https://www.r4i.tuc.gr/) addressing social inclusion in European Classrooms by applying an innovative methodology to combine music and dance to promote social, emotional and learning skills of students in mixed classrooms. The innovative learning approach to be explored promotes the use of rhythm to enhance the students' skills and promote an atmosphere of collaboration and respect in the classroom. The central hypothesis is that rhythm could be used to promote student engagement and collaboration while at the same time promote the use of rhythm-based artistic techniques to manage the classroom and enable the effective inclusion of all children in the learning process including children with ADHD.

The use of the "ADDventurous Rhythmical Planet" game, in combination with other complementary tools and arts-based learning approaches, will make it possible to implement and evaluate an Art (music/rhythm -dance/movement) and Resilience based Intervention Curriculum in a number of schools across Europe in order to enhance teachers' scientific and practical knowledge, professional and personal skills and development. Specifically, the project will provide school teachers with a flexible and innovative training program to help them deal with mixed classrooms needs and be able to design and implement engaging learning activities using the "ADDventurous Rhythmical Planet" game and other similar tools. In this respect, the social and educational value of European cultural heritage will be also addressed via the selection of appropriate rhythmic patterns to be incorporated in the game play to form the basis for rhythm-based learning interventions for building inclusive

learning environments. Different European cultures will be combined, thus offering a rich multi-cultural body of best practices, materials and educational tools that will also promote the cultural awareness and mutual respect of European cultures. Non-European cultures that are closely related to European cultural heritage will be also involved as, for example, Easter music that is closely connected to traditional Greek music and music from other countries of the Mediterranean.

As it becomes apparent from the above, the "ADDventurous Rhythmical Planet" has made way for many new applications and creations to take place. Let this be the beginning for further research and support for children with ADHD though a playful and fun environment.

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A Appendix

A.1 Pilot Tool Evaluation

User 8-12 Questionnaire:

Sample Number:
Date:
Year Of Birth:
Gender: Male / Female
ADHD Diagnosed: Yes / No
Knowledge of English language: Yes / No
Musical experience: Yes / No

A. First Impression
A1. How does the user react when starting the game?

A2. Does the user need further instructions from the researcher to move around the environment?

A3. Does the user like the main character?

B. User Experience
B1. Degree of difficulty of the single play mode:

B2. Does the user need need guidance from the researcher in order to play the game?

B3. Which level did the user reach?

C. Record any difficulties:

D. Record general impression of the user regarding the experience:

Educator Questionnaire:

Sample Number:
Date:
Special Education teacher: Yes / No

A. First Impression
A1. What do you think about the environment of the game?

A2. Do you think a child with ADHD would be attracted to it?

A3. Do you think this game can promote collaboration?

B. User Experience
B1. In your opinion, what is the degree of difficulty of the game for children 8-12 years old?

B2. What do you think could be improved in this game?

C. Difficulties & Purpose Achievement
C1. Do you notice any difficulties that a child would face during the game? What are they?

C2.Do you think that the multi-player mode promotes collaboration? Why?

D. Record your general impressions regarding the game: