

ADDventurous Rhythmical Planet: A 3D Rhythm-based Serious Game for Social Skills Development of Children with ADHD

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Abstract. Children diagnosed with ADHD are often at a disadvantage regarding their social interactions at school and at play due to their symptomatic inattention, impulsivity and hyperactivity. That may lead to isolation, low self-esteem and even depression. 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. This paper presents a multimodal 3D serious game named "ADDventurous Rhythmical Planet". Its goal is to exploit the benefits of music and rhythm helping children diagnosed with ADHD to overcome their psychosocial challenges, unlike currently available games offering interaction based on only the visual modality.

Keywords: ADHD, social skills, music therapy, rhythm, psychosocial functioning, serious game

1 Introduction

This paper presents a 3D game for children diagnosed with ADHD (Attention Deficit Hyperactivity Disorder) of 8-11 years old, aiming to improve their social collaborative skills using rhythm and music. ADHD is a chronic neurobiological disorder which affects the brain structurally and chemically as well as the ways in which various parts of the brain communicate with one another. It is a cluster of difficulties that involve the self-management system of the brain. People with ADHD struggle to concentrate on specific actions as well as get organized, regulate emotions and impulses and generally, regulate and use their working memory.

There are three types of ADHD: Inattentive, Hyperactive, and Combined [7]. 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. 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 [1] [14]. Consequently, an important aspect of ADHD is lack of structured thoughts. In order to address it, music therapy approaches can be used taking into account that music entails rhythm, which is essentially a structure of patterns in time [3]. Thus, rhythm as structure helps soothe the mind of children with ADHD by helping the ADHD brain stay on a linear path and, therefore, get more organized, instead of drifting around as it normally does.

In general, 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 [8], reduce hyperactivity, externalize feelings and improve mental health. Indeed, when children learn how to play a musical instrument, sing, or even listen to a whole track of music, they are required to focus on the task. This way their hyperactivity is controlled because, they learn how to stay in one place and channel their excess energy to the task at hand, since making music requires both energy and concentration. Such improvements help children with ADHD make progress at school and be more social in all aspects of their life. Furthermore, they can develop cognitive ability, acquire self-confidence and understand the idea of limits and rules. Cognitive ability improvements are based on the fact that music shares neural networks with other cognitive processes as shown during brain imaging experiments [16]. 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 [15].

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. [11] [10] [17] [6]

The work reported in this paper, leverages results and experiences on the potential of music therapy of children with ADHD in order to develop a video game that is based on musical rhythm as an interface. Video games, in general, make it easier for children with ADHD to focus their attention with minimal effort. Video games are already one of the few areas where kids with ADHD can exercise cognitive skills. Games demand that they pay attention, even for a short time. Players must focus in order to achieve the goals of the game. During play, there are consequences that correspond to each action, both good and bad. This is an important concept to be grasped since it applies in the real world as well.

In addition, video games provide instant feedback, which is helpful for children with ADHD in order to improve their symptoms. Children with ADHD 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.

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. Based on this process, 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. 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. Feedback should be frequent and instant in relation to the action that the player takes during gameplay.

The paper is organized as follows: Section 2 presents previous work on video games for children with ADHD. Section 3 presents the main features of the "ADDventurous Rhythmical Planet" game. The architecture of the game and the special hardware employed are described in section 4. Section 5 describes the details of game play and how the various game screens and levels are organized. Section 6 presents aspects related to the game environment and what kind of learning activities are supported. Conclusions and Future work are presented in section 6.

2 Related Work

Digital games for children with ADHD target either the diagnosis or symptoms' improvement. 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 even working memory, cognitive flexibility and inhibition control.

Previous research has put forward an interesting game named as "Adventurous Dreaming Highflying Dragon: A Full Body Game for Children with ADHD" [9]. 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 provides a practice space for attention and aims to increase the ability to focus and remember specific visual prompts. The second one aims 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, controlling impulsivity. This game requires full body engagement of the player.

The game named "ANTONYMS: A Serious Game for Enhancing Inhibition Mechanisms in Children with ADHD" [2] 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. Moreover, the "ChillFish: A Respiration Game for Children with ADHD" [18] focuses on breathing exercises and how they can help the children to control their stress level. Based on 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.

The EVO Project [4], [13] 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, for example, include guiding an alien spacecraft through a canyon. 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 players skill level and as the game progresses, it gradually increases the speed of the ship and the number of objects the player must hit adding blue birds to the mix, for example.

The games analyzed above mostly employ the visual sensory modality, requiring children to interact with mostly visual worlds and related game play. In this paper, 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 which we hypothesize will enhance the social skills of children diagnosed with ADHD.

3 Main Features of the "ADDventurous Rhythmical Planet" Game

The 3D game presented in this paper focuses on improving the psychosocial/ psychoemotional issues instead of the cognitive function of players diagnosed with ADHD 8-12 years old. These issues could be either stress, low self-confidence, sociability and classroom inclusion. 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 [5]. The innovative aspect of the "ADDventurous Rhythmical Planet" game is that it is multimodal, exploiting the proven benefits of rhythm and music as analyzed in the previous section. Moreover, the "ADDventurous Rhythmical Planet" game is multi-user, offering a unique multimodal collaborative experience which requires the collaboration between the players in order for the game play to advance, so that social skills are improved. The game is based on children holding drums equipped with sensors which transfer children's collaborative drum playing actions to a 3D visualized game.

The design process that was followed consisted mainly of numerous brainstorming sessions as well as counselling by psychologists, special education teachers, special education music teachers and the musician Mr John Papatzani 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 their drums. Such actions will be translated to game play progression in the game environment. This idea was based on the material that Mr John Papatzani employed during extensive rhythm seminars that he has taught to educators in relation to how to incorporate rhythm in the class activities. The educators applied rhythm practices in their class without digital material and have reported positive results in relation to enhancing collaboration, learning and a sense of fun in the class. Rhythm related practices are integrated in the game using playful and fun ways. Pilot testing in schools will follow right after the completion of the prototype.

The "ADDventurous Rhythmical Planet" game promotes atomicity and expression of self since each player uses a drum. Rhythm includes the ideas of geometry and consistence 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 game 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 Architecture and Hardware

The game's central interaction affordances are happening through a drum that each player is holding. 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. 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.

To facilitate flexibility and tolerance to player inaccuracies, a real number is calculated as a measure of similarity between the performed rhythm by the player and the target rhythm that is provided by an expert musician. Furthermore, the expert musician provides rhythmic samples that are perceived as resembling to the target rhythm by humans 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 an evaluation metric that represents the correctness of the input rhythm.

The Unity real-time development platform is used as the basic implementation environment of the game. An SQLite database is used for persistent storage of data. 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. The architecture is shown in Figure 1.



Fig. 1. Architecture of the game

5 Game Play

Each player is using a drum to create a rhythmic pattern, as already presented. The drum actions are translated to game play actions in the visual environment of the game. The game hero is an extra terrestrial shown in Figure 2. She 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 game 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 will learn and practice, by helping the hero of the game, on identifying rhythm patterns and how to reproduce them. In multi-user mode, the players will have to cooperate and collaboratively create rhythm in order to complete their mission. As a result, each player, in collaboration with the others, will be 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 game is centred around the main character, who crashed on a foreign planet. She now has to move around the planet from one game level to the other. The mechanical parts of the spaceship have fallen inside the craters of the planet and this fact has made the craters angry. In order to acquire the missing parts, players will have to play a beat so that the angry craters soothed. In other words, completing a game level involves players performing specific rhythmic exercises with their drums.

The players' goal, in single-user mode, is to find the parts of the spaceship that went missing. In multi-user mode, the alien with her new friends, are trying to acquire tools and repair the spaceship in order to continue the journey. In the single-user mode of the game, when completing each level, the character will be receiving a clue, such as a footprint, that will help find her friends. In the multi-user mode, when completing a level, the main character and her friends will get a new tool to help them fix the spaceship.

6 Game Environment and Learning Activities

The game environment consists of a main menu, a statistics board, a menu for the sound and also a user selection interface between single- and multi-user mode as shown in figure 3. When the game starts, the story of the game unfolds and the menu that appears asks for the player's name and age. The player can select an already existing name to resume from a previous game session. Every new player starts in single-user mode which is the introductory part of the game. 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.

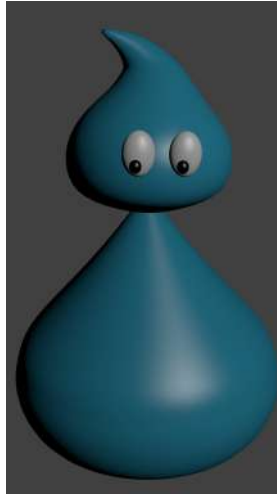


Fig. 2. Main Character of the Game - All the 3D models of the game were created using Blender, a 3D computer graphics software toolset

The Game Mechanics related to learning [12] that this game uses are numeral. 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.

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/>) to promote social inclusion in European Classrooms by applying an innovative methodology to combine music and dance to promote social, emotional and learning skills of students focusing on mixed classrooms. The innovative learning approach to be explored

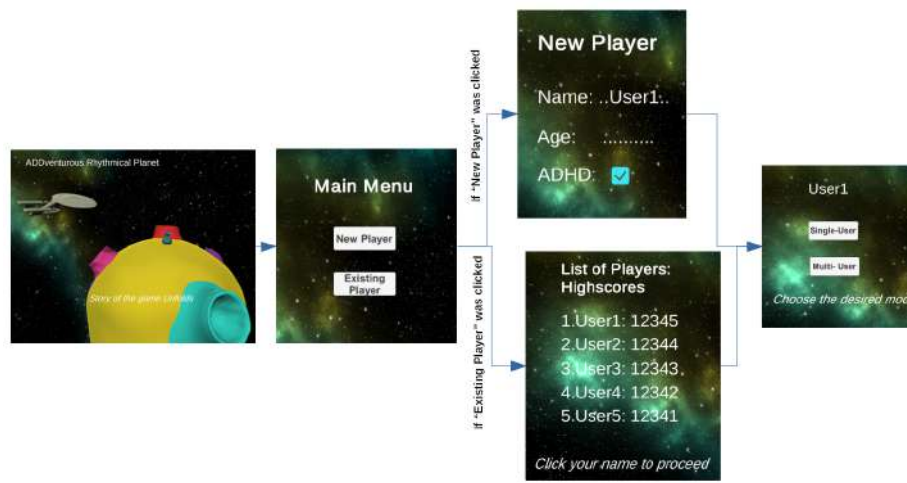


Fig. 3. Main Menu

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.

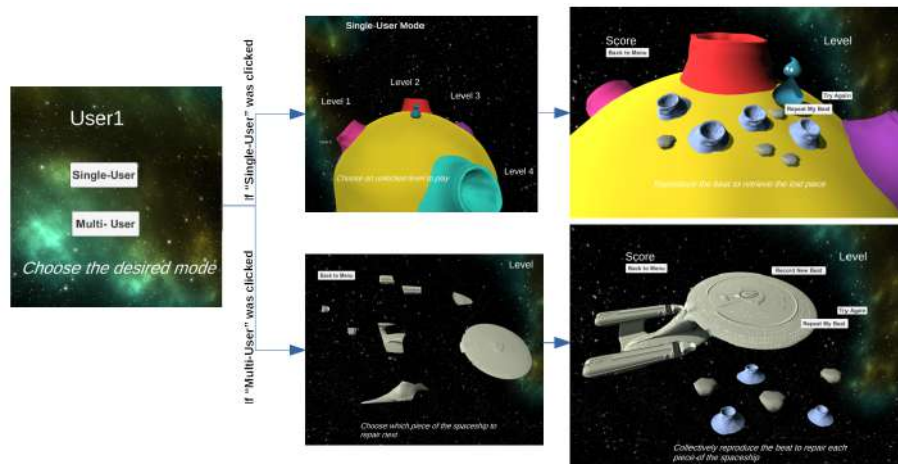


Fig. 4. Single and Multi User Modes

7 Conclusion & Future Work

The "ADDventurous Rhythmical Planet" game presented in this paper aims to offer its players the capability to improve their social skills and learn to cooperate with other children, focusing on children diagnosed with ADHD.

In order to evaluate the game, 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) will be used for this purpose. SDQ is a brief behavioural screening questionnaire about 3-16 year olds. It exists in several versions to meet the needs of researchers, clinicians and

The goal is that as the game's development progresses, it will be able to monitor the progress of the player and dynamically adjust its difficulty. 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 their diagnosis. Based on detailed data logs, parents and specialists can be informed of the ongoing progress of each player.

The game aims to not only help the child 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 could also be useful for the transition from one level of school to another.

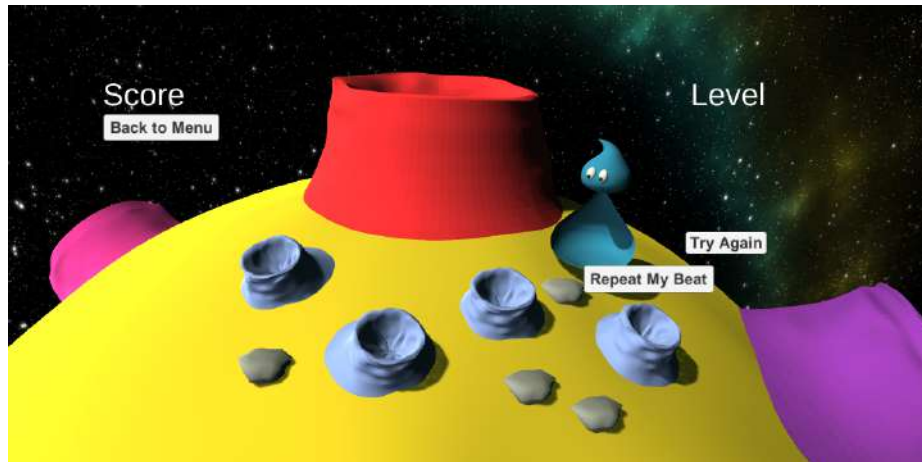


Fig. 5. single player / tutorial mode

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The "ADDventurous Rhythmical Planet" game will be extensively used and evaluated within the context of the Erasmus+ project Nr 2018-1-SE01-KA201-039032 "rhythm4inclusion - Promoting Social, Emotional, and Learning Skills of Students with and without Special Education Needs by Developing Teachers Capabilities in Music, Dance and Digital Competences" (<https://www.r4i.tuc.gr/en/home/>)

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