Serious Game con RV basado en musicoterapia aplicado al mejoramiento del aprendizaje de niños con TDAH

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Virtual Reality Serious Game Based on Music Therapy Applied to the Improvement of Learning in Children with ADHD

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Abstract. Attention Deficit Hyperactivity Disorder (ADHD) is a disorder with significant impact on child neurodevelopment. Various research studies have provided evidence of the efficacy of two therapeutic approaches that have proven to be effective in the treatment of ADHD, specifically virtual reality games and music therapy. However, these studies have addressed these treatments independently, without directly comparing them. Therefore, the purpose of this study is the design and implementation of a serious virtual reality game based on music therapy, emphasizing the attention difficulties present in the learning of children aged 8 to 12 with ADHD. The results obtained from this study show data evaluated by a specialist that demonstrate the efficacy in ADHD patients when serious games are applied in combination with music therapy. These patients show a fluid and uninterrupted involvement in the activities, on the contrary, their involvement is altered when these interventions lack the incorporation of music therapy.

Keywords: ADHD · Immersive learning · Music therapy · Serious games · Virtual reality

1 Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects approximately 5% of children worldwide [1]. Children with ADHD have difficulty with attention and impulse control, which can lead to poor academic performance. The incorporation of digital resources has proven to be a promising alternative in the treatment of ADHD, these programs use interactive activities such as video games to improve attention and focus. Video games specifically designed to address ADHD difficulties can have a positive impact on improving executive functions and reducing ADHD symptoms [2].

Virtual reality (VR) and music therapy offer a unique and engaging approach to ADHD treatment because they can help improve these skills and enhance learning. VR games allow children to become fully immersed in a virtual environment, which can be especially helpful for children with ADHD to practice concentration and task tracking. Currently, there are memory assistive devices that help people with ADHD

to remember tasks, unlike these devices, which may have limitations in terms of accessibility, music therapy offers a therapeutic option through the use of immersive sounds that can effectively complement each other to improve attention span, these sounds allow for continuous neural stimulation and association between visual and auditory organs [3]. Emotions evoked by music have gained an important place in the psychology of emotions and affective neuroscience [4], music has the ability to regulate emotions and provide a sense of comfort and support, this can be especially beneficial for children with ADHD, who often face challenges in managing their emotions.

Several studies have shown that VR and music therapy can be effective treatments for ADHD: i) Immersive VR-based interventions have been shown to be effective in improving global cognitive functioning, attention and memory in children with ADHD [5]. The researchers used a systematic review and meta-analysis approach to evaluate the efficacy of immersive VR therapy in the treatment of ADHD. ii) The application of music therapy as an alternative treatment for depression in children with ADHD showed positive neurophysiological and psychological effects [6]. This study was conceived following a randomization-based approach to ensure the rigor and validity of the results obtained.

These studies suggest that VR therapy and music therapy may be promising new treatments for ADHD as a safe and effective alternative that helps children with ADHD improve their attention. Despite the promising results, these studies have approached ADHD treatment using different approaches. One study focuses on the use of virtual reality as therapy, while the other focuses on music therapy. It is important to note that both approaches have been investigated independently, without combining or directly comparing them.

The instructional design identified to support the various areas of ADHD in this proposal involved an approach based on the principle of personalization, in order to provide a more effective therapeutic experience tailored to each user. The objective of this study is the design and implementation of a serious game that combines virtual reality with the effects of music therapy, focused on those attention difficulties in the learning process of 8 to 12-year-old children with ADHD. The results of this study could lead to the development of new and effective treatments for ADHD, facilitating the academic performance of childrens affected by it.

2 Methodology

For the development of the serious game, the Kanban methodology was used. This methodology focuses mainly on workflow optimization and visual management thus allowing to improve efficiency, it is suitable when time to market and innovation are critical [7]. By employing Unity as the game engine, it was possible to create an attractive and dynamic virtual environment, capable of capturing the attention of children with ADHD. The combination of visual, audio and interaction elements specifically designed for this population helped to maintain their interest and engagement in the virtual environment. During development, special attention was paid to integrating the specific needs of ADHD into the software design process. To

achieve this, a user-centered approach was adopted, in which the main challenges associated with ADHD, such as inattention, impulsivity, and difficulty solving tasks and maintaining concentration, were identified. These aspects served as a guide to design activities and game mechanics adapted to effectively address each of these problems.

The serious game scheme, shown in Fig. 1, is an essential tool for understanding and managing the interactions between the different elements of a project in the Unity environment. This scheme is divided as follows: within the Unity component, there are the Game Objects, which represent the visual and functional elements of the game. The inputs correspond to the actions or data that the system receives, in this case the user's movements. The outputs correspond to the system's generated responses to the executed actions. The scripts are fundamental to process the logic of the serious game, allowing the interaction between the inputs, the Game Objects and generating the corresponding outputs.

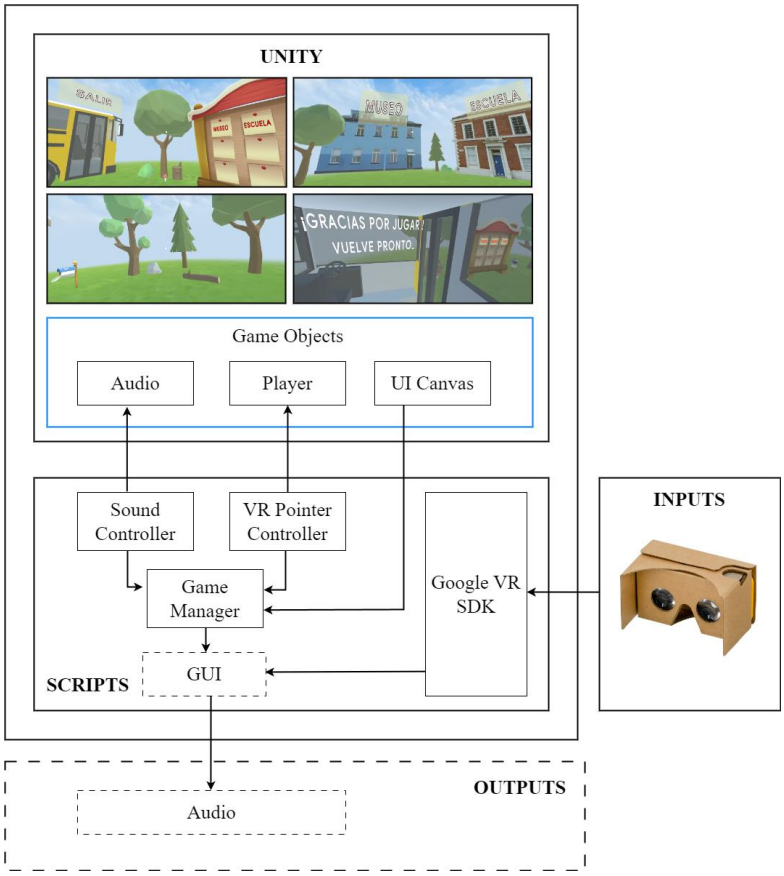

Fig. 1. Serious game scheme.

Unity acts as the main engine to execute and visualize the project, providing the necessary environment for the interaction and proper functioning of the serious game. With this scheme, it is possible to understand and optimize the flow of information and the interaction between the different components.

2.1 Game Process Overview

In the initial scenario of the serious game, players find themselves in a schoolyard where they can explore and familiarize themselves with the school environment before diving into the interactive activities. i) The first activity takes place in a museum, where players can move through the rooms while looking for the differences in each painting, this visual challenge allows them to test their observation and perception skills. ii) The second activity takes place in a classroom within the school. Here, players are faced with a blackboard full of mathematical operations. Their goal is to solve these operations correctly as fast as possible, this activity helps them develop their mathematical skills while enjoying the virtual reality experience in an educational environment. The use case diagram in Fig. 2 shows the main tasks that the user can perform in the virtual reality game. Through this diagram, the basic functionalities of the serious game present within its scenarios are also detailed.

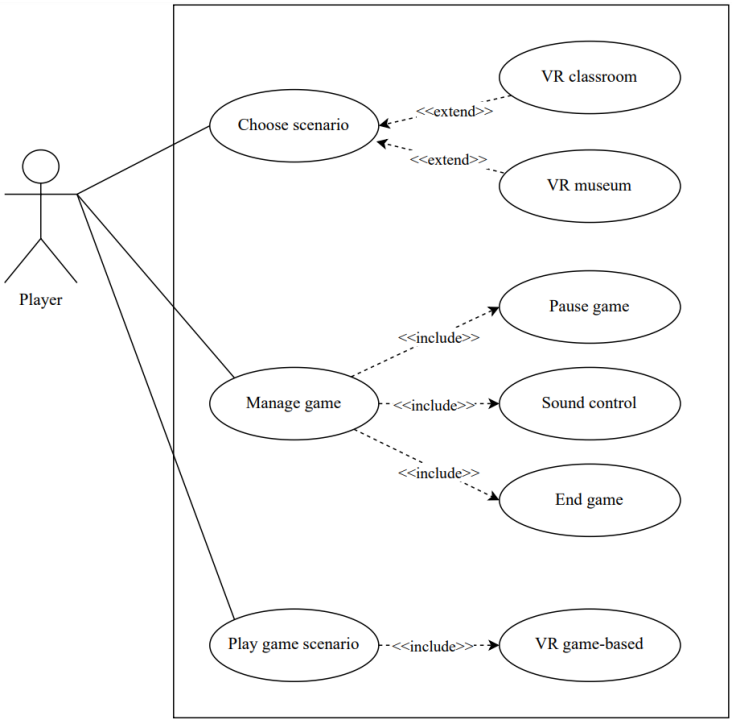

Fig. 2. Use case diagram representing user tasks.

By considering a broader context, one can accurately understand how the diagram in Fig. 3 represents the process of the virtual reality system that supports this serious game. In this diagram, four main layers can be observed. i) The first layer is the user, who interacts with the system using the VR Headsets to immerse himself/herself in the virtual world. ii) The second layer is composed of the VR Headsets, which are the input devices that receive the user interaction data and send it to the Unity game engine. This layer acts as a bridge between the user and the system. iii) The third layer is the Unity game engine, here the interaction data is processed and is responsible for generating the 3D graphics, managing the game physics and implementing the game logic. It is the core of the system that makes the virtual experience possible. iv) The fourth and final layer is the user interface, which interacts with the game engine. It is responsible for presenting visual and auditory information to the user in the virtual environment, providing an intuitive and attractive interface.

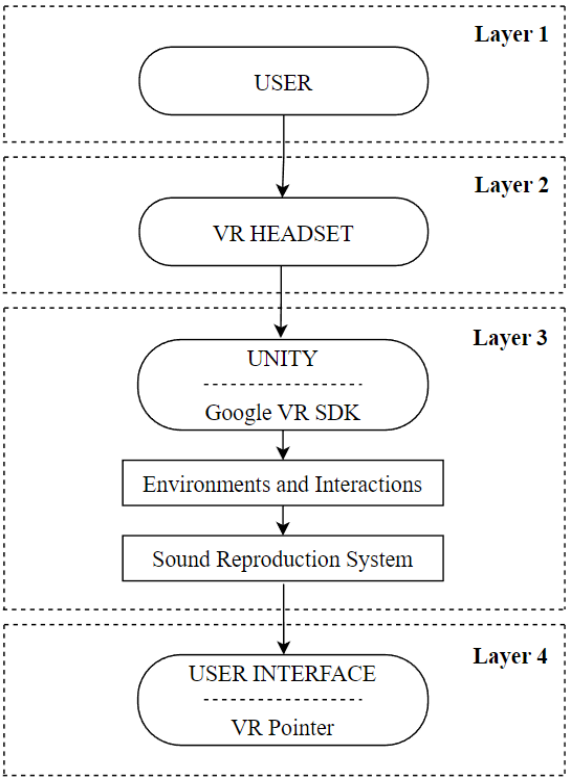

Fig. 3. Process diagram of the serious game.

Serious games offer a valuable opportunity for the development of cognitive skills in players, since both selective attention and sustained attention are essential

components in the treatment of ADHD, they are used as assessment criteria to measure outcomes. Selective attention is the subconscious process of focusing on certain information and ignoring other information [8]. Selective attention is enhanced by allowing players to focus on relevant in-game elements and filter out unnecessary distractions, which contributes to improved ability to concentrate. Sustained attention, meanwhile, benefits from providing players with challenging tasks that require prolonged focus. Daily life situations that require sustained attention often require higher levels of activation, frequent interactions with the environment, and flexible switching between tasks [9].

For the database design, a database diagram is presented in Fig. 4, comprising five interconnected tables to efficiently manage the essential aspects of the game.

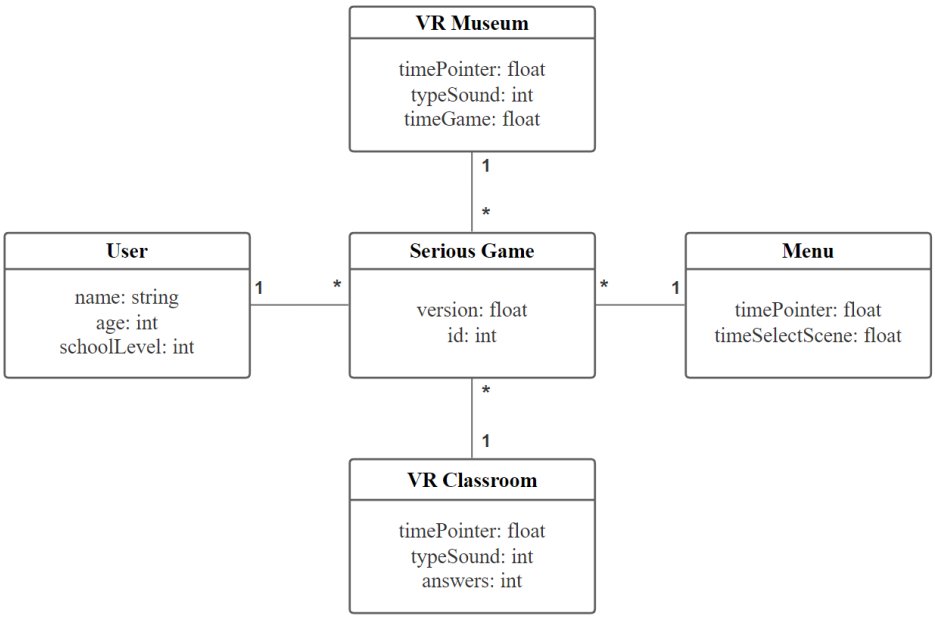

Fig. 4. Database diagram.

The "Serious Game" table stores general information about the available versions of the game. The "User" table captures user details such as name, age and school level. The "Menu" table is responsible for managing menu options and game settings. The remaining two tables are associated with specific scenarios, both tables record the type of sound that will be played. The "VR Museum" table stores information about the player's playing time. The "VR Classroom" table manages the answers of the mathematical operations. These five tables are designed to work together, allowing the game to store and retrieve information about the pointer's time to provide an immersive and personalized experience for users.

2.2 Music Therapy Integration

The integration of music therapy into the design of our serious game is a fundamental aspect to ensure an effective and meaningful therapeutic experience for users. We adopted a meticulous approach based on previous research in music therapy and sound psychology. The selection of sounds for each environment in the game was based on careful consideration of the specific therapeutic objectives for each situation. Aspects such as rhythm, melody, and tempo were taken into account to ensure that the chosen sounds were consistent with the desired therapeutic effects. To guarantee the appropriateness of the selected sounds, we worked closely with experts in music therapy and healthcare professionals to identify which sonic elements could support the sought-after therapeutic goals. The feedback obtained from this analysis was taken into account to refine and adjust the sounds, thereby ensuring their suitability for the therapeutic objectives.

The therapeutic music incorporated into the serious game was designed to induce specific emotional states in the players. Specially created musical compositions were used for the game, focusing on both relaxing and stimulating elements as needed for each scenario. Furthermore, the music is seamlessly integrated with the game dynamics to create an immersive and engaging experience that facilitates user immersion in the therapeutic process. The game dynamics of the serious game were constructed around key therapeutic principles. For instance, in levels aimed at promoting relaxation and calmness, activities were designed with slow tempo music and soothing harmonies. On the other hand, in situations where the objective was to enhance concentration and attention, energetic rhythms were employed.

2.3 User Interface in Virtual Reality

The user interface plays a crucial role in the development of virtual reality games. Since children with ADHD often face challenges related to attention, impulsivity and motivation, it is critical to design an adapted interface that provides appropriate visual and auditory stimuli, promotes active participation and maintains their interest throughout the game. Through a user-centered approach and careful adaptations, the aim is to provide an immersive and effective gaming experience that not only entertains, but also fosters the development of key cognitive skills.

It is relevant to consider the interface theory of perception; this theory provides insights into how our perceptual systems construct and interpret information presented in virtual environments [10]. By incorporating insights from this theory, one can better understand the underlying mechanisms of perception in virtual reality and optimize the presentation of sensory information to enhance the sense of presence and immersion for users.

In this context, the interface was designed with usability and accessibility principles in mind. Visually appealing elements with vibrant colors and playful designs were created to keep children's interest as shown in Fig. 5. Menus were simplified and easily recognizable icons and symbols were used to facilitate understanding and navigation. In addition, attention-enhancing strategies such as visual and auditory cues were implemented.

Fig. 5. Virtual reality lobby.

Immersion is a crucial factor for presence and can be influenced by interaction with the virtual environment [11]. In this regard, a VR Pointer is implemented whose importance lies in allowing players to point and select objects in the virtual environment, which contributes to a greater sense of immersion. A hoop-shaped pointer has been used that loads as a progress indicator, as shown in Fig. 6a, once the pointer fully loads the selection is activated, as shown in Fig. 6b. This design provides intuitive visual feedback during interaction, which helps users to have a clear understanding of the status of the ongoing action. This improves user perception and provides a more accurate interaction.

(a) (b)

Fig. 6. Sequence of virtual reality pointer.

2.4 Immersive Virtual Classroom

Since attention plays a key role in mathematical ability, research focused on the relationship between the inattentive domain of ADHD and mathematics may provide further insights into the disorder and the mechanisms of mathematical learning [12]. In this context, a virtual scenario representing a classroom is developed as shown in Fig. 7, where the user appears seated with the view towards the blackboard. The dynamics of the game starts when mathematical operations are presented on the blackboard, the user must select the correct answer using the VR pointer that is controlled by head movement. At the end of the activity, the time taken to complete the activity is displayed, per user.

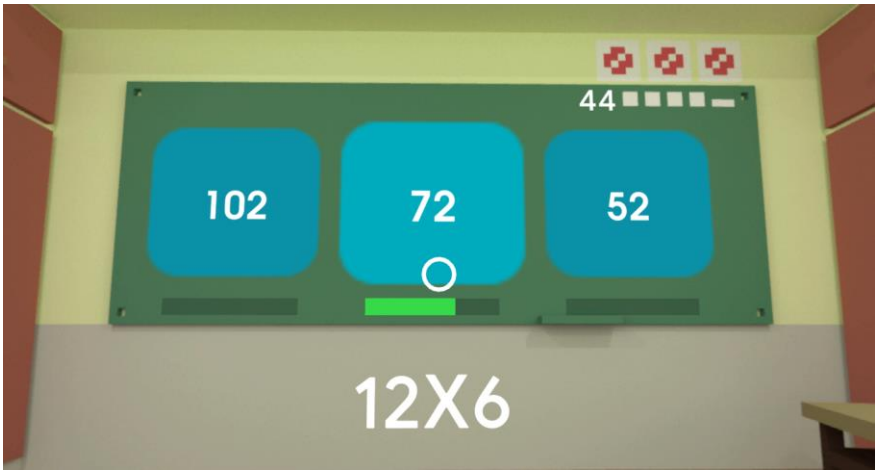

Fig. 7. Virtual classroom environment.

By combining interactive visual elements with auditory stimuli, using a dynamic of response selection, the game helps children to develop concentration in mathematical tasks. In addition, music therapy has been incorporated as an integral part of this game, by playing specific sounds during the game activities, seeking to take advantage of the therapeutic benefits of music in the emotional regulation and mood of children, which creates an environment conducive to learning and motivation, by providing an enriching and stimulating experience.

2.5 Immersive Virtual Museum

Games are rehearsals for real life and offer a natural way to stimulate different cognitive processes [13]. For this reason, a virtual scenario inspired by an art museum has been developed, where the user is in a corridor surrounded by several paintings. The game dynamics starts when the user selects a picture using the virtual reality pointer Fig. 8. The main objective of this game is to find the differences between two

apparently identical images but with small hidden variations. The user must identify and point out all the differences within a given time.

Fig. 8. Virtual museum environment.

Like the previous game, this one incorporates music therapy by playing background sounds during the activities. This musical technique aims to create a pleasant and stimulating environment, which contributes to the user's concentration and focus during the search for differences in the game.

2.6 Participants

For the research, a sample of 30 children between the ages of 8 and 12 years with ADHD was taken, to whom the immersion of reality was applied through the use of a serious video game in safe virtual reality environments, 15 children received the treatment using virtual reality and music therapy and 15 children received the treatment using virtual reality without music therapy, this while playing sustained attention and selective attention games once the VR headset was attached, without much effort and almost without realizing that they are receiving a treatment. This research helps to assess both positive and negative aspects of serious game-based treatment.

The user profile further includes both genders, to ensure a complete representation of the target population it was taken into account that ADHD patient is in the predominant degree of presentation with hyperactivity and impulsivity previously detected by the specialist Neuropsychologist in Education, this degree of ADHD is more common in men having a ratio of 4:1.

3 Results

This section shows the results obtained from the use of virtual reality technology and music therapy in children, which through behavioral psychological tests is used to compare the behavior of a child with others of the same age, as shown in Fig. 9.

Fig. 9. Neuropsychologist diagnosing ADHD patients.

Table 1 shows the sample of children who are treated privately by the specialist, who belong to different educational institutions and their age ranges from 8 to 12 years old.

Table 1. Total children by psychological condition and age.

School Grade	Age	Children	ADHD	Other Psychological Conditions
2	8	24	10	14
3	9	18	6	12
4	10	8	4	4
5	11	10	4	6
6	12	16	6	10
Total			**30**	**46**

Subsequently, with the supervision of the Neuropsychologist in Education, music therapy sessions with low frequency sounds were carried out. Table 2 below shows the most important aspects evaluated by the specialist in one of the patient's sessions. After completing the 10 sessions of which 1 is included in this article, an analysis and evaluation was carried out, where it is important to note that data are collected on the disposition and situation of the patient and taking into account that each patient did not require time to adapt because the serious video game was intuitive and had the instructions to perform each of the activities of the virtual reality environment

Table 2. Aspects of music therapy to consider, session 4.

Phase of the session	Activity	Development objectives	Evaluation indicators
Preparation and introduction	-Dialogue about their emotions -Opening song	-Start -Relax	Relaxed atmosphere -Attentive listening
Motivation for the session	-We talked about music and their preferences. -We listen and sing	-Listen to -Recognizing sentences -Working memory -Escuchar -Recognizing phrases -Working memory	-Effort in memory activities -Reinforcement of self-esteem
Relationship with the other (externalization)	-Rhythmic exercise -Relaxation activity	-Fortalecer vinculo musicoterapia-paciente	-Feeling of "being capable". -Increased attention
Farewell	-Farewell song	-Strengthen the use of memory -Appreciate learning	-Reviewing what has been learned -Excitement to come back for the next session

In addition, correct performance was also evaluated through the application of items from a questionnaire of perception of use and satisfaction applied to children diagnosed with ADHD, this questionnaire consists of 9 reagents, as shown in Fig. 10.

Reagent	Answer
Did I find it easy to understand the game?	Liker scale
Did I enjoy trying the game and the musical sounds?	Liker scale
Did you feel the immersion of the game?	Liker scale
Did you feel happy when you finished the game?	Liker scale
Did you feel calm at the end of the game?	Liker scale
Did you feel annoyed at the end of the game?	YES/NO
Would you play it again?	YES/NO
What did I like the most about the game?	Open response
What would you change about the game?	Open response

Fig. 10. Questionnaire reagent applied to children with ADHD.

The first 5 items refer to the perception of use of the serious video game using a Likert scale [14] from 1 to 5 being 1 totally disagree and 5 totally agree, the last 4 items refer to the satisfaction after using the serious video game, items 6 and 7 are answered with yes and no. The last 4 items refer to the satisfaction after using the serious video game, where yes will take the numerical value within the tabulation of 1

and not the numerical value of 0 and items 8 and 9 are open questions to know the opinion of the child and make improvements to the system, based on the items and the time in minutes which the metric that was used in each of the video games of sustained and selective attention can evaluate the correct performance of patients.

The research compiles the scores obtained from children regardless of gender (male and female) who were exposed to this treatment with the use of virtual reality in the museum video game and classroom video game. The support of virtual reality to therapeutic treatments is considered a new phenomenon, therefore experts on the subject are needed to help us know the effectiveness of the application of serious video games with virtual reality, with identifiers such as the percentage of sustained attention, percentage of selective attention, percentage of visual attention and percentage of musical attention, based on this, the following criteria were taken into account with respect to the time spent in each video game. For the museum virtual reality environment, the time to solve the video game was 15 minutes maximum and 7 minutes minimum, being this value more effective to solve the video game adapting it with music therapy, while applying it without music therapy the time to solve the video game was 26 minutes maximum and 18 minutes minimum per patient. For the virtual reality classroom environment, the time was a maximum of 10 minutes and a minimum of 5 minutes adapting it with music therapy, while applying it without music therapy the maximum time was 25 minutes and a minimum of 13 minutes. This means that the more minutes used in the development of each of the video games, the lower the percentage of effectiveness of the treatment and the less minutes the higher the percentage of effectiveness of the treatment.

Table 3. Percentages obtained in serious game with music therapy.

Videogame	Sustained Attention	Percentage	Selective Attention	Percentage
Kid	**Music Therapy ON (Minutes)**	**%**	**Music Therapy ON (Minutes)**	**%**
1	7.2	100	6.4	94
2	13	77.5	5.8	94
3	7.5	96.25	5.5	94
4	14.7	70	9.3	76
5	7.3	100	6.9	88
6	11.1	85	8.5	76
7	9.9	88.75	8.1	82
8	12.4	81.25	7.7	82
9	8.2	96.25	7.3	88
10	8.9	92.5	5.3	100
11	7.3	100	9.4	76
12	8.6	92.5	8.1	82
13	12.5	77.5	5.1	100
14	13.3	77.5	9.9	70
15	10.2	85	9.7	70
Average Acceptable Percentage		**88**		**84.8**

Table 3 shows the percentages obtained by the children after playing the virtual environments with the use of music therapy within the immersion of each scenario, which are in the acceptable range for continuous improvement with the application of virtual treatment, because the sounds help the improvement and concentration of children suffering from ADHD.

Table 4. Percentages obtained in serious game without music therapy.

Videogame	Sustained Attention	Percentage	Selective Attention	Percentage
Kid	**Music Therapy OFF (Minutes)**	**%**	**Music Therapy OFF (Minutes)**	**%**
1	19.4	40	13.9	36.67
2	21.8	20	16.5	26.68
3	23.1	15	18.1	23.25
4	18.7	35	21.3	13.36
5	24.2	10	14.6	33.34
6	20.6	25	23.7	3.33
7	25.3	5	15.2	33.34
8	22.9	15	20.4	16.69
9	18.2	40	24.8	0
10	26.0	0	14.3	36.67
11	20.3	30	19.7	16.69
12	18.6	35	22.1	10.03
13	19.8	30	17.6	26.68
14	21.5	20	25. 0	0
15	25.7	0	13.4	40
Average Percentage not Acceptable		**21.33**		**21.13**

Table 4 shows the percentages obtained by the children after playing the virtual environments without the use of music therapy within the immersion of each scenario, which are not very far from the reality in which the participants are involved, since they find factors that distract them from the environment and need feedback or internal help to refocus on the activity they were performing.

Based on this research study and the results obtained, the use of 3D virtual and safe environments shows a great acceptance and support in the use of video games because practice and persistence will improve the results. In short, VR and music therapy enable children to learn and develop specific skills in a safe environment that can be transferred to a real environment. In addition, music therapy in conjunction with virtual reality ranges from immersion in 3D environments and listening to music to constitute a model of perception and hearing to influence brain functions such as in this case the patient's behavior [15].

4 Discussion

Virtual reality (VR) and music therapy offer an engaging and unique approach to treating ADHD, improving skills and enhancing learning. VR games allow children to immerse themselves in virtual environments, especially beneficial for those with ADHD to practice concentration. Music therapy, through immersive sounds, improves attention and neural stimulation. Therefore, the expectation is that VR and immersive music therapy will lead to further therapeutic improvements. [16]. The schematization of the educational video game in Unity is based on components such as Game Objects, inputs (user actions) and outputs (system responses). The scripts process the game logic, allowing interaction and output generation.

The educational game begins in a schoolyard where players explore before interactive activities. An activity in a museum tests observation and perception, while another in a classroom challenges math skills in a VR environment. The user interacts with the system through a VR headset, which interfaces with the Unity engine. This processes interaction data, creates 3D graphics and manages the game logic. The user interface presents visual and auditory information in the virtual environment. Virtual reality (VR) video games can provide realistic, simplified, and safe experiences in which children with ADHD could experience learning situations tailored to their unique learning needs [17]. The design of selective sustained attention training tasks should take into account the influence of collaborative environments on training performance [18].

5 Conclusions

The research proposes virtual reality environments with music therapy as a support to specialists who treat patients with ADHD diagnosis such as psychologists, neuropsychologists and other professionals in this field so that they can monitor children suffering from this disorder through the use of sustained attention and selective attention video games, in which, as shown in the results, patients perform effectively when immersed in virtual reality environments with the help of music therapy while patients do not perform effectively when playing the aforementioned video games without music therapy, where as future work will be implemented the management of a database in the cloud for the creation of a website that can be managed by the specialist.

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