

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

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 to develop a serious game that integrates virtual reality with the benefits of music therapy, emphasizing the attention difficulties present in the learning of children aged 8 to 12 with ADHD. The results obtained from this study could substantially contribute to the development of innovative and effective therapeutic approaches for the treatment of ADHD.

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 objective of this study is the development 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 students 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.

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.

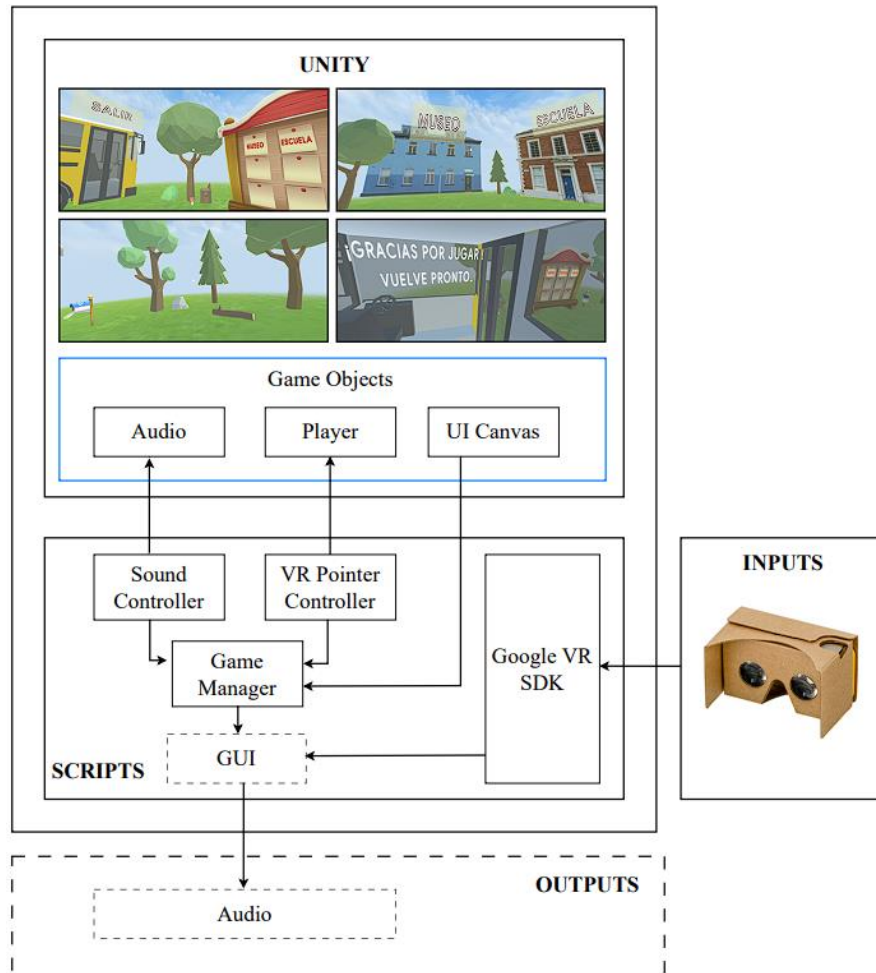


Fig. 1. Serious game scheme.

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.

By considering a broader context, one can accurately understand how the diagram in Figure 2 represents the process of the virtual reality system that supports this serious game. In this diagram, four main layers can be observed.

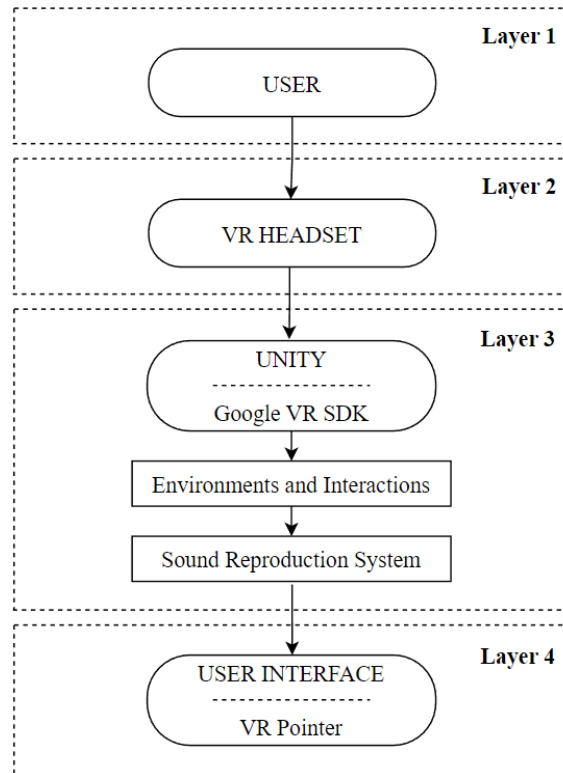


Fig. 2. Process diagram of the serious game.

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.

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].

2.2 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. 3. 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. 3. 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. 4a, once the pointer fully loads the selection is activated, as shown in Fig. 4b. 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.

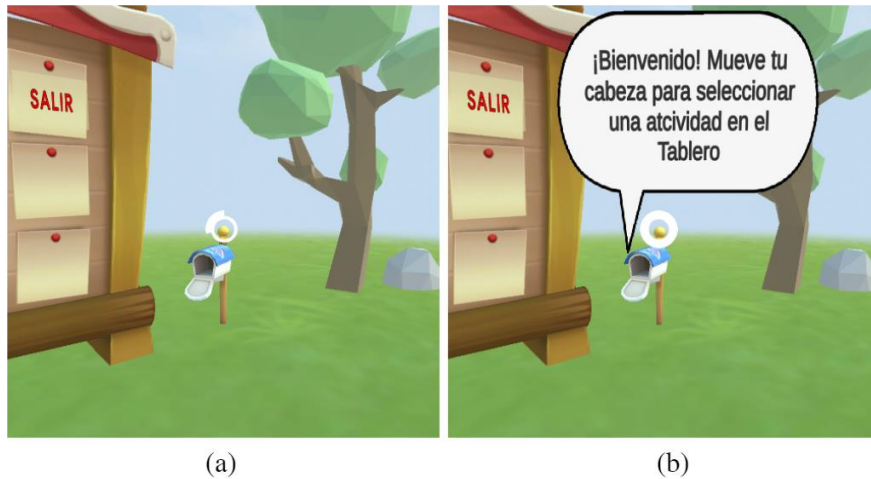


Fig. 4. Sequence of virtual reality pointer.

2.3 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. 5, 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.

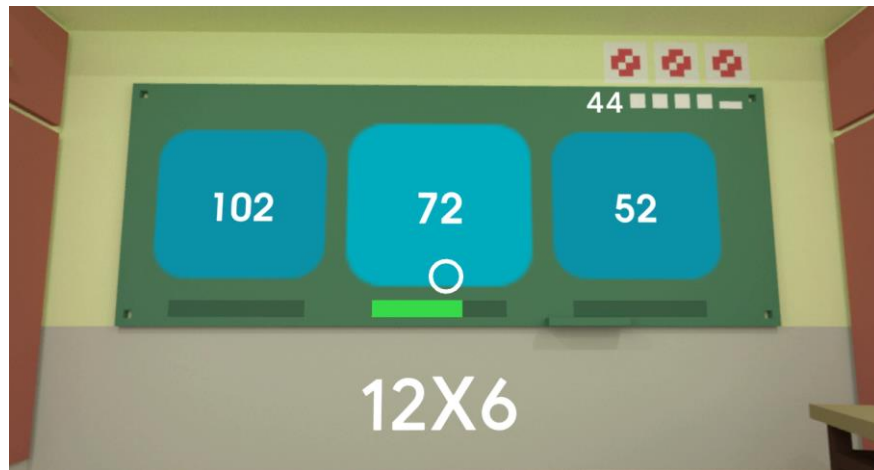


Fig. 5. Virtual classroom environment.

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.

2.4 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 6. 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.

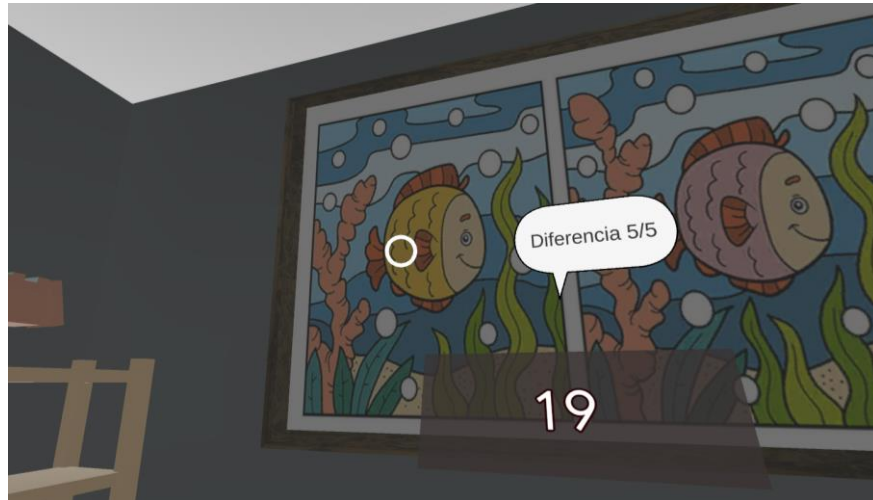


Fig. 6. Virtual museum environment.

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.

3 Results

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 they put on the Google Cardboard, without much effort and almost without realizing that they are receiving a treatment, since the best way to learn is through video games. This research helps to assess both positive and negative aspects of serious video game-based treatment.

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 1. Acceptable percentages obtained in video games with music therapy.

Videogame	Sustained Attention	Percentage	Selective Attention	Percentage
Kid	Music Therapy ON	%	Music Therapy ON	%
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 1 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 2. Unacceptable percentages in video games without music therapy.

Videogame	Sustained Attention	Percentage	Selective Attention	Percentage
Kid	Music Therapy OFF	%	Music Therapy OFF	%
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 2 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 [14].

4 Discussion

Children with ADHD require therapy once the disorder is identified, all this with the great boom of technology where alternative ways to traditional treatment are sought, one of these, the immersion of virtual reality with the help of music therapy.

Therefore, the expectation is that VR and immersive music therapy would lead to further therapeutic improvements. [15]. This can lead to the child having more difficulty in daily life, having even more severe concentration problems, followed by negative attitudes and thus being a compulsive person, which can lead in the worst-case scenario to becoming violent.

The difficulties that are detected for children suffering from this condition may be involved from social, academic or work situations in adult ages, the same that are summarized in difficulties to perform their daily tasks or activities with order, also the difficulty of performing multiple activities that are summarized in paying attention to the teacher and make notes for later study. 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 [16]. The design of selective sustained attention training tasks must consider the influence of collaborative environments on training performance [17]. Taking this into account the percentages of sustained and selective attention are at 84.8% and 88% of effectiveness respectively, when a serious video game with virtual reality is used to contribute to the treatment of children suffering from ADHD with the help of music therapy, compared to 21.13% and 21.33% of effectiveness respectively, when applied without music therapy.

5 Conclusions

Virtual reality and music therapy were fundamental in the support for an alternative treatment for children suffering from ADHD since when using the sustained attention and selective attention games we obtained a percentage of 84.8% and 88% when using the video game with music therapy, proving the effectiveness of the video game versus the percentage of 21.13% and 21.33% when not applying it with music therapy, which shows us the great drop in concentration that children have when using the video game without music therapy.

A serious video game with virtual reality provides an alternative to the traditional treatment for ADHD with the use of immersive 3D environments that help the child to improve memory and loss of concentration.

Sustained attention and selective attention games were developed, both with and without music therapy for the identification of improvement in the child's learning and impulsive control.