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Electronic, VR & Augmented Reality Games for Intervention in ADHD

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Abstract. In recent years, there has been an increase in the incidence of ADHD in children and adolescents. Many learning and behavioral problems are associated with this disorder as a result of difficulties in cognitive and metacognitive functions. According to Drigas et al. (2021), only when individuals develop these functions can they be integrated in the social environment. Skills such as self-awareness, self-regulation and self-control through inner attention can help children develop alternative strategies to manage their cognitive deficits and adapt in many different environments. With the rapid development of science, several medical and psychological methods have been proposed for the treatment of ADHD, which have contributed significantly to the control of symptoms. In the present work, alternative forms of intervention are investigated, such as video games, with virtual or augmented reality environments that aim to improve the quality of life of these children.

Keywords. Attention Deficit Hyperactivity Disorder (ADHD), Social/Emotional Development, ICTs, Metacognition, Video Games, Virtual Reality, Augmented Reality

1. Introduction

According to Drigas & Driga (2019), Attention Deficit Hyperactivity Disorder (ADHD) is a complex neurological disorder, which still lacks scientific data concerning its nature and treatment methods. Some factors, such as the family's socioeconomic status, the existence of a psychiatric disorder in the mother, or smoking and alcohol consumption during pregnancy, have been proved to play an important role. The main symptoms of ADHD are lack of attention and impulsivity, resulting from a malfunction in areas of the brain that control executive functions. These functions, such as memory and attention, lay the foundation for an individual's organizational skills, their ability to focus on tasks, control of emotions, and the ability to self-evaluate.

In order to control the symptoms of ADHD, a therapy based on the development of cognitive and metacognitive skills is required. According to Drigas et al. (2021), cognitive and metacognitive skills evolve progressively via an individual's self-awareness of their strengths and weaknesses, their self-observation, self-regulation, adaptation and flexibility in diverse areas (cognitive, emotional, and behavioral), recognition, discernment and mindfulness. People with high social and emotional intelligence are capable of better self-monitoring, a skill that is necessary to control behavior in children with ADHD (Drigas & Papoutsis 2018). Emotional

intelligence focuses also on the individual's character and aspects of self-control, such as regulating impulses, which is one of the predominant difficulties of these children (Matthews et al., 2004). According to the 9-level model (pyramid) of emotional intelligence of Drigas & Papoutsis (2018), a person must go through the following stages to reach the highest level of Emotional Intelligence, which is Emotional Unity:

- 1) Emotional Stimuli (coding of emotional senses, attention)
- 2) Emotions' Recognition, Perception/Expression of Emotions (memory, perception, recognition, emotions' identification)
- 3) Self-knowledge (self-perception, awareness, self-observation)
- 4) Self-management (self-regulation, flexibility, self-control)
- 5) Social Awareness, Empathy, Emotion Discernment (awareness, monitoring, social recognition & flexibility)
- 6) Social skills, Specialization in Emotions (reflection, management of social problems)
- 7) Universality of Emotions, Self-actualization (self-perfection, self-completion)
- 8) Transcendence (self-reflection, transcendental knowledge)
- 9) Emotional Unity (pure consciousness & fullness)

The seventh level, "self-actualization", is at the top of Maslow's hierarchy of needs. In order to achieve this condition of becoming, it is necessary to meet needs at lower levels of the pyramid, such as the need for survival, security, social acceptance, and self-esteem (Maslow 1943, 1987). Only when people with ADHD meet their needs, develop their emotional intelligence and improve their metacognitive skills will they be able to master the appropriate cognitive and socio-emotional skills that will allow them to integrate into the social environment (Drigas & Mitsea 2020; Drigas & Mitsea 2021). Medication is considered a first-choice treatment to reduce the symptoms. However, it has several disadvantages due to the side effects caused and the risk of addiction. On the other hand, intervention tools such as new technologies have proved to be just as effective.

2. 2D Video Games

Hakimirad et al. (2019) investigated the effectiveness of the EmoGalaxy video game on the social skills of children with ADHD. The concerned study was conducted in two groups (experiment and control), and the study population included children with ADHD. Specifically, 20 boys aged 7 to 12 years were selected and randomly divided into the experimental group (10 children) and the control group (10 children). The experimental group did fifteen (15) 45-minute long intervention sessions using EmoGalaxy, while the control group did not receive any specific intervention. The students' social skills were assessed via the Gresham & Elliot (1990) Social Skills Assessment Scale before and after the intervention.

In the EmoGalaxy video game the player must travel between four planets. Each planet refers to one of the primary emotions: happiness, sadness, fear, and anger. In each part of the planet, the player can play different games. The game is designed to intervene in three areas of emotional capacity, i.e. emotion recognition, emotion expression, and emotion regulation. For example, on the "frowning" planet anger-related abilities are being exercised. In order to access any game, the player has to show and express the feeling of anger. Through the front camera the game captures the users' faces and recognizes their emotional expression. If the player cannot express the right emotion, the game asks him to recognize an angry face among the characters in the game. In other words, it evaluates a rather basic level of emotional capacity, i.e. recognition. Players receive a score after completing each game. When a player's score

reaches a certain level, they collect enough fuel for their spaceship and can travel to the next planet that corresponds to another emotion (Hakimirad et al., 2019).

EmoGalaxy can be played on Android smartphones and tablets with operating systems 4.4 and above, iPhone 5 or later models, and on PCs. The game is two-dimensional and was developed through the Unity 5 application. The results showed a significant difference in the social skills test scores before and after the intervention. EmoGalaxy increased the level of collaboration by 0.46, assertiveness by 0.59, responsibility by 0.25, and self-control by 0.47. The overall social skills were affected by 0.73. According to the results of this study, EmoGalaxy, as a cognitive video game, had a positive effect on all components of social skills of children with ADHD (Hakimirad et al., 2019).

Prins et al., (2013) developed the game "Braingame Brian" to improve the executive functions in children with ADHD. "Braingame Brian", named after the main character Brian, consists of 25 activities lasting 40 to 50 minutes and has seven different worlds: The area around Brian's parents' house, the village, the uninhabited island, the backlands, the beach, the swamp, and the basement workshop. All characters that live in these worlds have a problem. Brian helps them solve these problems by completing cognitive exercises.

An external support system is used to enhance the child's motivation to complete the training. Data from each training session are sent to a central database. Based on this data, educators receive online feedback on the child's progress. The study included 40 children diagnosed with ADHD (8-12 years old) who were divided into two groups, the experimental group that received intervention through "Braingame Brian" (n = 18) and the control group which didn't receive any form of intervention (n = 22). Questionnaires were given to parents and teachers to assess the difficulties in executive functions, the symptoms of ADHD, and any disruptive behavior problems, before and after the intervention. The results showed that children improved significantly their executive functions (Gioia et al., 2000) and ADHD symptoms (Inattention and Hyperactive-Impulsivity subscale of the Disruptive Behavior Problem Scale) (Pelham et al., 1992). This pilot study shows much promising evidence on the effectiveness of this program. However, "Braingame Brian" should not be considered an autonomous form of treatment but should complement or be integrated in existing ADHD interventions, such as pharmacotherapy and behavioral therapy, in order to deliver therapeutic results (Prins et al., 2013).

Wrońska et al. (2015) introduced a new interactive game designed to improve reading and comprehension skills in children with ADHD. The LyC (Lectura y Comprensión) game was developed for the iPad and is based on techniques used in health-promoting serious games. That research was conducted in a control group of six children (two boys and four girls) of typical development and aged 8 to 12 years, who were not diagnosed with ADHD. The game was developed using an Apple iPad 2 running on iOS 7.2, the XCode 5 programming platform, and the SQLite and MySQL databases. Its content was based on attention-catching exercises during reading and image observing, which are available on the website (Programa de Entrenamiento de Instrucciones Escritas Nivel Medio, 2013). Specifically, the application consists of nine interactive exercises of different levels of difficulty, and the game includes three stages. First, the player must read the text that contains critical information. Then, he must comprehend and process the information. Finally, the player must select the correct answer among the multiple given answers. The answer is selected by dragging and dropping a button from the toolbox to the correct image.

The evaluation of the game consists of two parts. First, the evaluation of data that contain the scores of the children who played the game, and second, the evaluation of the

system's usability based on the SUS questionnaire. Two parameters were recorded during each child's assessment: the time they took to complete each exercise and the overall score of answers (for every wrong response, the corresponding score was 0). These results were sent to the SQLite database, which stored them on the device. Immediately after completing the game, the children were asked to complete the SUS questionnaire to evaluate the game's usability. The questionnaire consisted of ten sentences, each of which had to be graded using the Likert scale that ranges from 1 (strongly disagree) to 5 (strongly agree) (Wrońska et al. 2015).

The outcome showed that the game is user-friendly and easy to complete, as confirmed by the SUS questionnaire's score. The study's main findings were that in the first stage of the game, the participants explored how to play, and the rules were not very clear to them. Also, age and gender differences were not as significant as the game evolved (Wrońska et al. 2015).

3. Virtual Reality (VR) Games

Yanguas et al. (2021) designed a video game using virtual reality (VR), which included a gamified chess version called "The Secret Trail of Moon" (TSTM). *Chess* is a game based on simple rules but requires a high cognitive level that includes among others attention, executive functions, and memory (Song et al., 2020; Langner et al., 2019). TSTM aimed to create an innovative and motivating tool for the cognitive therapy of patients diagnosed with ADHD. This video game consists of 6 work areas. Each area is designed to improve a different area of disability in patients with ADHD: attention, working memory, planning, spatial capacity, impulse control, and reasoning. The video game's innovative approach is the usage of chess as a main feature. In TSTM, chess appears in three different forms: A) As a work area, which consists of chess lessons and exercises B) As a central theme of the work area, where the elements of the chessboard and its pieces are used for cognitive exercises, not needing however to know the rules of chess. For example, in the "Smasher" game the player must pay attention to press the X button on the game controller whenever the "pawn-horse" sequence appears. C) As part of the video game plot. For example, the player is in a forest with chess elements who narrate the history of this particular world. During his journey, along with the animals that accompany him, he will unlock information about the relationship between the forest and chess. The ultimate test of the video game is to play a game of chess against the enemy.

The initial design of the video game has been revised following a user-oriented model (Fullerton, 2014). During the usability study, the researchers received feedback from patients who tried different video game versions. This feedback allowed them to make improvements in the game's layout, according to the needs and preferences of the patients. The Unity Game Engine and Sony PlayStation VR were used to develop the video game. The study involved 105 patients diagnosed with ADHD and on regular medication who were randomly divided into 1) Control team, 2) Online chess therapy team, and 3) TSTM team. All patients and their parents were assessed before and after the intervention. The training lasted 12 weeks. The central hypothesis was that the patients trained in TSTM or in online chess would improve their executive functions compared to the patients who do not participate in any intervention (control group) (Yanguas et al., 2021).

The results showed that TSTM was fun, understandable, easy to use, and with appealing graphics, resulting in adequate participation of most players. Also, the patients in the TSTM intervention group improved their executive functions more and had fewer undesirable behaviors than those in the online chess intervention group or in the control group (Yanguas et al., 2021).

Yang-Kun et al. (2020) used virtual reality games as means of intervention for attention, abstract reasoning, and complex information processing in children with ADHD. This study includes two stages: In the first stage, semi-structured interviews were conducted with psychotherapists and physiotherapists in order to understand the treatment methods for children with ADHD and to evaluate the difficulties so as to develop guidelines for what games to select. In the second stage, the virtual reality game console HTC VIVE (HTC, Taiwan) was used to develop a 3-month, three-times-per-week training program for children with ADHD. The study involved three children aged 8-12 years, diagnosed with ADHD but without any other illnesses or disorders and who had not previously received any VR-based training.

During the sessions each child's parents were present in the room but did not participate in the game. The experiment consisted of three designed games, which focused on exercising the visual-motor coordination ability of the participants and had different levels of difficulty. Participants were assessed through four tests, before and after each session: 1) Non-verbal intelligence assessment (fourth edition) TONI-4 (Mungketklang et al. 2016), 2) Attention test for primary school children (ATESC), a scale developed in Taiwan by Lin and Chou (2010), 3) Wisconsin Card Classification Test (WCST) (Heaton 1981), 4) The Chinese version of the revised Swanson, Nolan, and Pelham (SNAP-IV) (Swanson et al. 1992).

Within each 3-week cycle, the difficulty level increased from beginner to advanced. In the final three weeks, each child decided for himself/herself which game it would play during the sessions. The researchers compared the children's attention, abstract reasoning, logic, and complex information processing before and after this program. The results revealed that the children with ADHD improved their attention span, hyperactivity/impulsivity, and decreased provocative behaviors. More specifically, in terms of performance regarding intelligence, cognitive function, and critical thinking, the results of the TONI-4 assessment revealed that participant A increased his score from 78 to 87, participant B maintained his score of 84, and participant C achieved the highest progress in his score (from 65 to 83). In total, participants' scores improved after the experiment. The ATESC results showed that the participants' scores in the five attention exercises improved particularly after the experiment. One participant improved his abstract reasoning and information processing, while the other two showed reduced performance. Participant A made fewer persistence errors, while participants B and C did not improve their performance in this area (Yang-Kun et al., 2020).

Bland'on Diego et al. (2016) used in their research the virtual reality 3D video game Harvest Challenge to assess and train attention and self-regulation in children with ADHD. Attention levels were mapped from 0 to 100 percent, using a Brain-Computer Interface system (MindWaveBCI) by placing an electrode on the frontal lobe. In addition, EEG signals were recorded in the state of resting. Neurofeedback therapies and interactive games are therapeutically ideal; they improve the disorder's symptoms due to the high motivation they create (Drigas & Bravou, 2012).

Two intervention sessions were performed in a specialized local institution (Instituto de Audiolog'ia Integrated-IdeAI) with the participation of nine children aged 5 to 12 years and diagnosed with ADHD. The 30-minute sessions were divided into two phases, the first lasting 5 minutes and the second lasting 25 minutes. In the first phase, the child listened to soothing music while being monitored using the MindWave device that recorded their EEG signals through the OpenViBE open-source software. In the second phase, three different stages of interaction were developed:

- 1) Equipment: The game starts with adventure sports in an ecological farm. The first goal for the player is to collect the equipment needed for a safe ride, which requires an

increase in attention levels (more than 50%) and following of rules. Players must effectively choose a helmet, a pair of gloves, a rope, and sneakers through the visual stimuli they see on the screen.

- 2) Path repair: The player must reach the top of a mountain to get the rope. For this reason, a series of wooden stairs were placed on a long path where some disasters occurred. Therefore, players will need to increase their level of attention to repair the track.
- 3) Carrot Harvest: At this point players interact with virtual objects. The user is placed in a big field of carrot harvest and is equipped with a basket to collect as many carrots as possible, raising and maintaining his/her attention levels until the vegetables are collected. If players reduce their attention levels, the carrots hide under the ground, thus not being collectable. The video game ends after time is up (30 minutes) (Bland'on Diego et al., 2016).

The results showed that by playing the video game Harvest Challenge, the children improved their performance, which reflects an enhanced ability to maintain continuous attention and self-regulation (Bland'on Diego et al. 2016). The results also showed a higher activity in alpha and beta waves that are widely associated with hyperactivity (Lansbergen et al., 2011).

4. Augmented Reality Games (AR)

Barba et al. (2019) created the program BRAVO (Beyond the tReatment of Attention loss hyperactiVity disOrder). This virtual and augmented reality environment applies rehabilitation exercises in the form of serious games for children with ADHD and supports therapists in managing the rehabilitation program.

The child is the main user of the system. Once the child is in front of the treatment room, an automatic face recognition procedure activates the system's authentication process, and the child meets with his/her personal virtual avatar. The avatar will always be friendly disposed towards the child's psychological profile so that they always feel welcomed by a familiar face. In addition to being displayed on a screen at the entrance and exit of the treatment room, the avatar also accompanies the child during the entire treatment process in the form of a digital hologram (displayed via Microsoft Hololens) (Barba et al. 2019).

The BRAVO platform collects data via sensors (EEG helmet and bracelet to detect pressure levels and performance during the game), processes the user's emotional state, and exchanges data with other system components facilitating game adjustments in real-time. It also contains a therapist's toolkit, which can be used to monitor treatment and to obtain suggestions regarding the game and recommended difficulty levels (Barba et al., 2019).

The BRAVO environment consists of three serious games that will be aiming to enable compliance with rules and to improve attention, prediction of outcomes of actions and social skills.

- 1) Topological Categories: The game is designed to be played via an HTC Vive and a controller, allowing the user to move in a virtual environment just as they would in a real one. In the game, users will explore three different environments (a classroom, a bedroom, and a garden), where they will be asked to complete particular tasks.
- 2) Infinite Runner: This is an 8-level game, aiming to educate on respecting the rules, active listening, and awareness of the player's limits. The game will be played using a Kinect device that allows the game avatar to move simply by using the human body: in fact, the player's movements are decoded without the need of wearing any additional equipment. Inside the game, the user is placed in a virtual environment that depicts a

country or a city street, where he is asked to follow a path while running. As the game progresses, the player must maneuver in the right directions to avoid various obstacles or to collect any requested item.

- 3) Space Travel Trainer: This is a 7-level game with the educational goal of teaching patients to plan their actions and manage their social relationships. The game is controlled via the Kinect device, which allows the detection of the player's hands movements. In the game, the player acts as an astronaut who aims to direct the spaceship to the planet of his friends. During his/her journey, he/she has to face various challenges: he/she needs to learn how to solve complex problems, how to make the right decision at the right time (improving his decision-making skills), but above all, how to interact with the members of his/her team (in order to defeat the enemy) (Barba et al. 2019).

The final stage of BRAVO will run for 27 weeks to evaluate the benefits. For this purpose, 60 new patients will participate, divided into the following age groups: 1) 3-6 years, 2) 6-9 years, and 3) 9-12 years. Each age group will be randomly divided into two other equally sized groups. The first group will serve as a control group undergoing traditional treatment, while the second will be the test group, receiving the new treatment in the augmented and virtual game environment. During the administration of treatments both groups will be assessed in three phases: before, during and after the intervention. In order to assess the real impact of the BRAVO system, usability and effectiveness tests will be applied (Barba et al., 2019).

Alqithami et al. (2019) aimed to design and simulate a cognitive model that can be used as an alternative intervention to traditional CBT (Cognitive Behavioral Therapy). This model takes advantage of current augmented reality developments to engage patients both in real and virtual game-based environments. Augmented reality combines real and three-dimensional virtual content through an interactive environment (Azuma, 1997). Compared to virtual reality that portrays the real world in 3D graphics on a computer screen (Burdea & Coiffet, 2003), augmented reality optimizes interactions with 3D objects in a real environment (Billinghurst et al., 2015).

The augmented reality game of Alqithami et al. (2019) was designed using the Microsoft-HoloLens emulator and the Unity application, and was tested in a case study. This game simulates two 3D balls: one is the target ball, while the other is not. The player must follow the instructions and hit the target ball in a specified time period to be counted as successful hit. If he fails doing so, his attempt will be added to the sum of unsuccessful hits as an omission or error. The child may play several rounds of the game during one therapy session. The number of rounds played depends on their performance during the game and their overall skill level. Each game consists of 10 one-minute trials. In each trial the "target" and "non-target" balls will appear to the child. During the trial the child will be directed to catch the target ball so to drop it during the trial interval. The time elapsed from the beginning of the trial to hitting the target is the response time. If the response time decreases, this indicates that the child's performance has improved. If the child is not able to catch any of the balls, this omission error may indicate inattention. If the child catches the non-target ball, this error indicates impulsivity (Alqithami et al., 2019).

This study was divided into two parts. The first part, examined the effect of successful and unsuccessful attempts on the performance index, while the second part assessed the effect of the child's involvement. The results showed an improvement in the child's attention to select the desired object, which added positively to his performance index. Alqithami et al. (2019) argue that through augmented reality games, every child can develop traits such as adaptability, smartness, responsiveness, and accuracy. They also consider that using AR environments is

more appropriate than VR environments, as it allows children to observe their current position while a game is introduced in their space.

Avila et al. (2018) aimed to improve attention in children with ADHD using Augmented Reality Serious Games (ARSG). Through a prototype game called ATHYNOS, they tried to emphasize the therapeutic benefits of using an AR environment. The purpose of ATHYNOS is to develop cognitive skills such as visual-motor coordination, feedback, interactivity, problem-solving, and selective and focused attention. Unity 3D in combination with Software Development Kit (SDK) and Vuforia Engine was used to develop the game. Regarding the game's graphics, Adobe Illustrator was used to develop the images (characters, scenes, scripts, and environments), Adobe After Effects for animation, and Adobe Premiere Pro for professional video editing. Finally, listening tools such as Ableton Live and Adobe Audition were used to create a music sequence.

At the beginning of the game, the therapist explains the procedure. Then, in order to start the game, each child must log on via one of the six avatars. After that, a main menu of scenes appears, containing two types of treatments (Missing Character, and Shape and Match) with three levels of difficulty, depending on the child's abilities. Shape and Match, for example, contains basic arithmetic operations, geometric shapes, sequences, and mathematical reasoning. The aim for the child is to match objects on the left side of a scene with those on the right and move them together to the center of the screen. In the end, the results are displayed (Avila et al., 2018).

The research was conducted with 11 children with ADHD (9 boys and 2 girls), aged between 7-10 years. There were 8 sessions per participant. In each session, the time for completing the activities was recorded. The descriptive statistical analysis that followed confirmed that the participants who played ATHYNOS during the eight sessions managed to improve significantly their time management and social skills in their daily life. The findings showed also that the players' attention meliorated, improving in turn their ability to handle frustration and reducing significantly the time needed to complete the game. It was also observed that the children's times and successes were homogeneous in both cases, thus showing that all the children had similar abilities. Avila et al. (2018) argue that this game promotes voluntary participation and requires a constant interest in problem-solving, contributing this way to the improvement of learning. In addition, according to the therapist's feedback, almost all children showed a great interest and motivation, a fact that made him feel highly satisfied.

5. Discussion

Playing a video game requires using executive, organizational and metacognitive skills. The most important utilized skills during games are memory and attention skills (Kulman, 2010). There is an interrelationship between memory and attention when performing a task. Their role is crucial to the cognitive functions of individuals with ADHD, since the higher the working memory level is, the longer is the attention span. Children with ADHD are more likely to have working memory deficits. (Angelopoulou & Drigas, 2021). Serious games, creating virtual and augmented reality (AR) environments through the use of new technologies, are ready to play a significant role in therapeutic interventions, especially in treating ADHD symptoms. In their study on the effects of hypnosis via virtual reality on children with disabilities, Drigas & Mitsea (2021) concluded that virtual reality (VR) environments could eliminate the symptoms of inattention, distraction, and hyperactivity. Furthermore, VR environments make participants' reactions faster and more accurate, cultivate many aspects of executive functions, and enhance emotional regulation.

Because children with ADHD get bored quickly, it is essential to attract their attention on a continuous basis. Video games make this possible because they require the child to remain focused and busy the entire time, and furthermore having all senses alert, which makes these games even more interesting for the user (Kulman, 2010). The findings of the present bibliographic research conclude that serious games with the use of ICTs have a positive effect on all components of social skills in children with ADHD (Hakimirad et al., 2019). Children improve significantly their executive functions and ADHD symptoms (Prins et al., 2013) and also exhibit less adverse behaviors (Yanguas et al., 2021). Furthermore, the research of Yang-Kun et al. (2020) revealed that through serious games children with ADHD improve their performance in attention, hyperactivity/impulsivity, critical thinking, abstract reasoning, and information processing.

Alqithami et al. (2019) argue that, through games in augmented reality environments, every child can develop traits such as adaptability, smartness, responsiveness, and accuracy. They assert also that AR environments are more appropriate than VR environments, as they allow children to be aware of their current position while a game is being introduced in their space. Participants who played their program improved significantly their time management and social skills in their daily lives, and improved also their attention, their ability to handle frustration, and reduced notably their time for completing gaming activities.

The discussion around the causes of ADHD and corresponding rehabilitation methods is a reflection of the fluidity of our knowledge in these areas. Further research is needed to develop alternative therapies with the use of serious games in virtual and augmented reality environments, to improve these children's cognitive and metacognitive skills and enable them to integrate into the social environment.

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