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VR & electronic games based Assessment for ADHD

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Abstract

Several automated tests have been developed in recent years (ADHD) to improve the accuracy of diagnosing attention deficit hyperactivity disorder (ADHD). Usually, it would be interpreted by medical experts based on a clinical history that included evaluation papers filled out by teachers, caretakers, or other relevant parties. Many experts have questioned this method of diagnosing ADHD because both medical professionals and caregivers are prone to subjective judgment. According to many studies, adopting new digital diagnostic tools in the form of games may provide much more essential diagnostic indicators for kids with ADHD. A game that fosters creativity sets distinct goals to be achieved, provides a feedback system that encourages players, and yields tangible outcomes that will appeal to kids more. Whether or not they are played in virtual reality environments, the present study looks at the use and effectiveness of video games to pinpoint ADHD symptoms.

Keywords

Attention Deficit Hyperactivity Disorder (ADHD), Assessment, ICTs, Metacognition, Serious Games, Virtual Reality, BCI

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1. Introduction

ADHD, also known as attention deficit hyperactivity disorder, is a neurological condition that affects children and adolescents most often. It still has a complicated character, and we must learn how it works. Lack of concentration and impulsivity are the primary signs and symptoms of ADHD, which are brought on by a disruption in the executive functions of the parts of the brain that control specific skills. An individual's socio-emotional health depends on their ability to exercise administrative functions, including self-regulation, flexible thinking, and short-term memory [1]. Additionally, cognitive capacity is a known predictor of academic achievement, whereas a child's worse academic performance due to personal weaknesses contributes to low self-esteem [2]. The basis for attention, organizational skills, selective concentration on tasks, mood management, and self-evaluation is laid through early control and development of these abilities [1].

Emotional intelligence is also linked to self-regulation, a crucial area where children with ADHD struggle. Emotional intelligence is the control panel for perceiving, thinking, learning, problem-solving, and decision-making. It also highlights the qualities of self-control, such as the person's ability to delay quick satisfaction, put up with irritants, and manage urges (strength of the ego). In their study, Drigas & Papoutsi [3] present a structured model for assessing and treating emotional intelligence that is made up of hierarchical stages that show an individual's improvement over time. This model may be used in real-world situations to assess special education, interpersonal relationships, and other facets of life. These levels are more precisely associated with receiving and identifying emotional cues, self-awareness, self-management, empathy, social skills, and self-actualization. Maslow's theory states that self-actualization is the most excellent form of self-fulfillment, self-actualization, and the pursuit of personal well-being [4-5].

A multilevel metacognition model put forth in another study by Drigas & Mitsea [6-8] contends that attention is at the "heart" of metacognitive abilities and takes part in operations like choosing, filtering, suspending, processing, storing, retrieval, predicting, monitoring, adjusting, adapting, recognizing, differentiating, remembering, and knowledge transformation. Each level in this paradigm describes a higher-ranking control system that shows the person's metacognitive growth. The development of a more complicated control system results from the shift in self-awareness and self-observation that occurs as one advances from the lowest to the highest levels of metacognition. It is possible to use this multilevel metacognition technique as a structured assessment model to meet the needs of students in various grade levels and school types. According to this perspective, the student is seen as a collection of evolving physical, emotional, cognitive, and spiritual needs.

Typically, parents and professionals fill out questionnaires to determine whether a child has ADHD. The fact that this approach is subjective and needs to evaluate the children's performance in the skills above suggests that it has several drawbacks. ICTs, on the other hand, are a crucial component of educational initiatives that attempt to manage and advance the sociocognitive abilities of children with special educational needs [9]. Since they motivate kids and can produce more objective findings, assessment techniques like serious games that use modern technology have shown to be equally as successful.

2. 2D Games

A Serious Game named "Antonyms" was created by Crepaldi et al. [10] as an alternative diagnostic tool for kids with ADHD. The user of Antonyms assumes the position of Atansyon, a super-hero entrusted with rescuing a kingdom on the opposite side of the world. Atansyon travels through four settings: Woodland (W), River Crossing (RC), Training School (TS), and Central Building (CB). The tasks and scenarios call for activities that need self-control, planning abilities, emotional self-regulation, control, attention to detail, and enhanced standby time. Antonyms should only be used in the presence of a therapist or activity supervisor. Each mini-game has a range of difficulties, so the challenges and complexity of the tasks increase as the player plays more. Additionally, the games offer near-instant feedback through visible and audio messages. Further, the player's behavior may be observed during the game, and their performance can be evaluated based on the various fault kinds (such as standby time errors and wrong responses) and completion times.

Sixteen boys between the ages of 8 and 11 worked as a team to analyze antonyms. Before participating in the trial, eight kids had ADHD diagnoses, while eight additional kids had neither ADHD nor any other neuro-developmental impairments. Two standardized tests, the Ranette and the Number Stroop assessments of the BIA test [11], frequently used to diagnose ADHD, were given before the game. The first one, Ranette, has the child color a frog whenever they hear a particular sound ("GO") and stop when they hear another sound ("STOP"). The 10-minute exam involves sustained attention, selective attention (the students had to choose the target sound), and suspension (the students had to control their impulsivity to continue). The second test, Number Stroop, uses stimuli that evoke two different and inconsistent responses, one of which—the answer that isn't chosen—is more impulsive than the other since it's an automatic reaction that is frequently given. Keeping track of the mistakes made during the exam measures the control and suspension of actions.

Data collected from children without ADHD revealed that their performance in the antonyms task matched the outcomes of the usual tests used to diagnose ADHD in the exact domains (i.e., control and suspension of impulsivity). The number of faults in the BIA Ranette sub-test precisely matched the problems in TS and CB. Children with ADHD also fared worse on the Antonyms test than typically do children of the same age who do not have ADHD. Because Antonyms offers a pleasant and user-friendly environment and is based on a neuropsychological task model that focuses on attention and impulsivity, these findings indirectly support the idea of employing it as a promising device in various evaluation procedures [8].

Delgado-Gómez et al. [12] suggest a video game in their study that is intended to measure distraction in kids with ADHD. In that kind of game, players control an animated character—in this case, a raccoon—to navigate around numerous hazards. The avatar must specifically hop over 180 holes along its course to prevent falling. Each of these gaps is divided into eighteen (18) squares, each of which is determined by the velocity of the avatar, the size of the trunk, and the size of the gap. The recommended videogame has a significant advantage over existing games that need special virtual reality equipment in that it can be played on any computer or smartphone. This makes evaluations possible at no expense. The game was designed utilizing the widely used Unity 3D game engine.

Twenty-eight kids, ages 8 to 16, diagnosed with ADHD participated in the study. The SWAN scale's inattention sub-scale, designed to evaluate ADHD, was completed by the appropriate caregiver or instructor while each child was doing the exam [13]. The findings revealed a substantial association between the children's level of inattention and the number of times the raccoon failed to leap. Additionally, this association gets more vital as the space between leaps is longer (i.e., for hops separated by more than two seconds). This might be explained by the fact that youngsters are entirely absorbed in the game while the time between leaps is brief, but they struggle to do so when the time between jumps is extended [12].

The experiment's findings revealed that children with an ADHD diagnosis had more skipped leaps and more jumps that were extremely near the gap. As a result, there was a significant correlation between the patients' distraction, attention deficit hyperactivity disorder symptoms, and average behavioral performance on the SWAN subscale. The authors of this study contend that this game has several primacies. This specific examination takes roughly seven minutes, compared to other methods that take over 15 minutes. Due to its time-constrained nature, this feature makes the game particularly interesting in therapeutic contexts. Second, since a standard PC or other device, such as a tablet or smartphone, is suitable, this evaluation approach does not require complicated or expensive technology, such as virtual reality equipment. As a result, the findings of the research and the characteristics of this specific video game make it an excellent tool for aiding professionals in diagnosing ADHD [12].

3. EEG-based Serious Games

GokEvolution is a video game that Serrano et al. [14] created to gauge the attention span of kids with ADHD. Attention was assessed by examining the EEG-BCI index that the NSMW gadget supplied while the individuals were engaged in the game. The primary drawback of these methods is that numerous scalp electrodes are needed for sophisticated EEG-BCI systems [15], which can be problematic when used outside of the lab. According to a new study, the NeuroSky MindWave (NSMW) technology can evaluate participants more efficiently and effectively, especially youngsters. An electrode that can transfer data through a Bluetooth connection must be positioned on the left side of the forefront to perform NSMW [16]. Numerous studies have used NSMW, establishing its suitability and reliability for determining emotional states [17-19] and managing attention [20].

A total of 52 kids—32 boys and 20 girls, with an average age of 8.98 years—without ADHD and 23 kids—18 boys and five girls, with an average age of 9.5 years—were assessed. None of the kids with ADHD were taking any medication during the research. Each kid's attention span and impulsiveness were evaluated using the CARAS-R Difference Test [21]. The objective of the video game GokEvolution was to grow and develop the main character. There were five degrees of difficulty (0-4). The character demonstrated his development by altering his hair color and style at each level. Each degree of difficulty increases the amount of attention needed. By paying as much attention as possible, players had to earn points and go on in the game; otherwise, they would lose points. The game's main screen, which displayed the players' attention levels (NSMW counter) and the points needed to win at each level through horizontal bars, allowed them to keep track of their performance (neurofeedback). Using the NSMW, the participant's left frontal lobe activity was monitored during the five-minute game to gauge their degree of focus. When the NSMW counter was between 0 and 50 or between 50 and 100, the game said the user was either paying attention or not. A player who could maintain concentration during the whole match would finish the five stages in, correspondingly, 5 s, 9 s, 14 s, 20 s, and 70 s. This indicates that the character development would be finished in around 2 minutes in a flawless performance [14].

The attention profiles of children with and without ADHD were ascertained using the variations in attention captured by the NeuroSky MindWave and paired with the findings of the CARAS-R psychological exam. When the kids were playing the video game GokEvolution, the NSMW gadget worked well in spotting attention shifts. At all game levels, the ADHD group showed less consistent attention than the control group. The researchers also concluded that the game could gauge the player's degree of focus based on their performance. For instance, the control group participants who completed every level may represent children with usual development. The results of this study suggest that the video game application might be utilized as a proactive diagnostic tool for attention-related problems when combined with the NSMW. Additionally, even though attention was evaluated in a non-clinical situation and only one electrode (Fp1, which is more limited than a multichannel electroencephalogram) was employed, the findings were entirely accurate [14].

An electroencephalogram (EEG) was used by Alaa et al. [22] to manage the severe game FOCUS to measure the degree of attention in children with ADHD. Due to the tremendous desire they produce, neurofeedback and brain-interface games are great for ADHD since they detect the disorder's symptoms [23]. The EEG signal is made up of several frequency bands: band (> 30 Hz), band (12-30 Hz), band (8-12 Hz), band (4-7 Hz), and band (4 Hz). Band (Gamma) is connected to problem-solving and memory, band (Beta) is related to quick activities, band (Alpha) is necessary for relaxation, band (Theta) is prominent

in drowsiness stages, and band (Delta) is predominant during sleep [24-25]. Each band is tied to a particular function. The EMOTIV EPOC+ or a keyboard may be used to play the game, created using the Unity Game Engine. A 14-channel wireless electroencephalogram tool called EMOTIV was developed for study into the computer-brain interface. Additionally, utilizing open-source software can deliver raw EEG data [22].

In FOCUS, the player aims to gather yellow-colored cubes as rapidly as possible while following instructions. The setting has a square floor that is enclosed by a forest. The two states are the " push " and the "neutral" states. The player must remain calm and steady when in the neutral condition. This is required to track the player's motions (the push state). To move the avatar ahead, the player must issue the orders. Either the keyboard or the EMOTIV can be used for this. In the latter, the EMOTIV wireless gyroscope tracks head motions to rotate the avatar left and right, increasing player engagement and giving the game a realistic feel [22].

Participants in the research included five people without ADHD (all men, 19 to 26 years old) and four people with ADHD (2 men, 18 and 23 years old, and two women, 21 and 22 years old). They were directed to play the game using both control modes, i.e., keyboard and EMOTIV, to gather the cubes. Their EEG signals were recorded in both situations. The findings demonstrated that while utilizing the EMOTIV rather than the keyboard, players were more engaged and focused on the game, perhaps because moving the character without pressing a button was more challenging. Additionally, the EMOTIV-controlled game took longer to finish because it was everyone's first time controlling an EEG game. Additionally, the classification of EEG data for participants without ADHD had an accuracy of up to 96%, and the type of EEG data for patients with ADHD had an accuracy of up to 98%. Identifying and diagnosing people with attention problems may be possible since playing concentration with EMOTIV rather than a keyboard necessitates a significant commitment to one's concentration and attention abilities [22].

4. Virtual Reality Classrooms

The goal of Yantong et al.'s study [27] was to determine if VR-based tests might be used to diagnose learning deficits in school-aged children with ADHD. According to several results, the application of virtual reality-based diagnostic tools represents a significant advancement in ADHD diagnosis, mainly because it enables realistic comparisons between control and ADHD groups [28]. More precisely, Drigas & Mitsea [29] found that these settings could identify the signs of inattention, distraction, and hyperactivity in their research on the impact of virtual reality on kids with impairments.

By contrasting the test's results with those of children in a control group, the validity of the VR test was thoroughly investigated. The participants were all students in grades 6 through 18. The children in the ADHD group were identified as having ADHD using the DSM-V diagnostic criteria [30]. The VR exam used the Virtual Reality Medical Center (VRMC) equipment. A high-tech computer with a resolution of 1,080 x 1,200 pixels, a refresh rate of 90 Hz, and a viewing angle of 110 degrees were used to measure the overall runtime performance. This gadget has a brain-interface system reminiscent of a video game, multiple sensors, position detectors, and an approach to gather data and facilitate statistical analysis. The VRMC method for assessing ADHD consists of three scenes: Position monitoring (30 items), Stroop (41 things), and object identification (60 items) are the first three categories. It takes 20 minutes to finish the entire exam. The test findings are illustrated by the use of four (4) indicators:

1. Accurate data (accurate responses)
2. Inaccurate information (wrong responses)
3. Accuracy (proportion of correct answers to all responses)
4. Duration of the entire exam.

The ability of participants (ages six and older) to maintain attention and control in the face of a range of multisensory (auditory and visual) stimuli was assessed using the IVA-CPT. Scales for acoustic control, auditory attention, visual control, and visual attention are all included in this test. Measures of behaviors associated with ADHD were also conducted using the Conners Parent Rating Scale (CPRS) and the Child Behavior Checklist (CBCL, ages 6-18) [27].

The results of the comparative research showed no appreciable differences in age or gender between the ADHD and control groups. The parameters linked to accuracy and the correct replies were significantly lower in ADHD youngsters than in the control group. Children with ADHD also took much longer than those without ADHD to finish tasks. The VR exam's erroneous responses were positively correlated with the CPRS hyperactivity score. In a previous study, Gilboa et al. [31] discovered a relationship between CPRS-R (Conners' Parent Rating Scales-Revised: Short) outcomes and VR (virtual classroom) assessment criteria in kids with acquired brain damage. These researchers claim that VR assessments might be valuable for identifying attention deficit problems.

Additionally, there was a correlation between the VR test errors and the CBCL evaluations for concentration problems, social skills problems, cognitive problems, and aggressive conduct. Finally, it was shown that there was a clear correlation between the time taken to complete the VR test and the quantity of visual and aural attention assessed by the IVA-CPT. The authors concluded that a VR test could identify ADHD symptoms, possibly qualifying it as an additional diagnostic tool [27].

Neguț et al. [32] contrasted the analog CPT (Computerized Continuous Performance Test) with a virtual classroom environment to evaluate children with ADHD. In the Continuous Performance Test (CPT), a type of assessment, participants must select a response to a specific aural or visual stimulus delivered at predetermined intervals. For the objective evaluation of kids with ADHD, many CPTs have been developed, such as the OPATUS CPTA assessment (https://opatus.se/). Previous studies have demonstrated that the integrated visual and auditory continuous performance test (IVA-CPT) may successfully discriminate between children with ADHD and control children [33]. Participants in the research ranged in

age from 7 to 13 and included forty-two (42) children without ADHD and thirty-three (33) children with ADHD. To be more precise, half of these kids (from both groups) underwent an evaluation utilizing ClinicaVR: Classroom-CPT, while the other half underwent a standard CPT evaluation.

The Cognitive Assessment System [34-35] evaluated the participants' general cognitive state. The Raven Standard Progressive Matrices Plus Romanian version assessed the participants' IQ. Additionally, a 15-sentence customized measure for kids was developed to rate their ClinicaVR experience on a scale of 1 to 5, depending on whether they had classroom CPT or regular CPT. (For instance, while I was playing on the computer, time appeared to fly by).

The participant in the ClinicaVR Classroom must respond as quickly as possible while holding back on undesirable behaviors while being exposed to stimuli for a prolonged time. The virtual classroom is a rectangle containing desks, a blackboard, doors, windows on either side, students, and an instructor. With 3D headsets, headphones, and glasses, the pupils were fully submerged in the classroom environment. In the game style, each player is seated at his desk and must react to targets on the blackboard. For instance, the learner only had to click the left mouse button when a specific letter appeared among the rapidly flashing alphabetic target objects on the board. In this process, distractions came in three different forms: acoustic (like a bus sound, door knock, step sound, and school bell), optical (like a paper falling, an airplane flying, or a teacher looking at her watch), and mixed (like a person walking into the classroom while the sound of a door opening) [32].

The neuropsychological tests were done by the kids first, and they were then either evaluated using the ClinicaVR: Classroom-CPT or the conventional CPT. The average stimulus-response time, replies, execution mistakes, and omission errors were assessed after this procedure, which took roughly two hours. Higher ratings showed greater ease of use, absorption, focused attention, delight, curiosity, and enjoyment [32].

ClinicaVR: Participants with and without ADHD were differentiated based on classroom-CPT results. Given that they provided less accurate responses, more omissions, and a slower response to the intended stimuli, children with ADHD, as predicted, received lower scores and in line with the findings of the standard CPT (Computerized Continuous Performance Test), individuals with ADHD provided more wrong responses in the ClinicaVR: Classroom-CPT than did participants without ADHD. Additionally, the outcomes differed depending on whether the examination was conducted with or without interruptions. In contrast to the analog CPT, the ClinicaVR: Classroom-CPT scenario showed a more significant rise in the symptoms of inattention in individuals with ADHD [32].

Three types of ADHD pupils (inattention type, impulsive type, and mixed type), and a control group, were the subjects of a study by Areces et al. [36] to compare the effects of the AULA Nesplora. ADHD may be diagnosed using AULA Nesplora in a virtual learning environment. Previous research has shown that AULA Nesplora provides more accurate and comprehensive information than the often-used CPTs [37]. This study employed a clinical sample of 90 boys and 27 girls aged 5 to 16. The individuals were divided into groups based on their level of ADHD using the Diagnostic and Statistical Manual of Mental Disorders [30]. They were divided into four groups: the control group, the group with inattentive ADHD, the group with impulsive ADHD, and the group with mixed ADHD. The families completed the ADHD Assessment Scale [39], and Wechsler's WISC-IV scale [38] was used to determine the total IQ (TIQ).

AULA Nesplora is the primary area of study [40]. Participants in this exam range in age from 6 to 16 and have their attention, impulsivity, sensory processing speed, and motor activity measured. The test is conducted in virtual reality while wearing 3D motion-detecting headset glasses and headphones (Head Mounted Display or HMD). The participant pretends to be a pupil seated at a desk in the classroom and concentrating on the blackboard. Sensors pick up every head movement on the glasses. As a result, the application alters the participant's point of view, giving the impression that he is in a virtual classroom. Three portions comprise the test, and a virtual teacher gradually explains each. For instance, the first stage is to completely submerge the user in the virtual reality setting such that he may visually locate and pop balloons [36].

The characteristics determined by the test above are equivalent to those defined by other conventional CPTs regarding attention deficit and hyperactivity/impulsivity. The following variables are evaluated in further detail:

1. Omissions: This error occurs when a person should have responded to a target stimulus but doesn't. This statistic gauges how focused and selective your attention is.
2. Commissions occur when a user clicks a button, even when the intended stimulus hasn't yet happened. This action is connected to a sensation of loss of control and suspension.
3. Average response time is a millisecond-based assessment of processing speed (reaction time).
4. Motor activity: Frequency and appropriateness of head movements are noted (i.e., necessary vs. superfluous motions).

There were variations between the control group and the ADHD groups, as was expected. There were disparities between the groups that shared the component of inattention (i.e., the inattentive and mixed ADHD-type groups) and the control group regarding the omission variable, with the first two groups displaying a higher deficit. In terms of the commission variable, there were variations between the groups that shared the trait of impulsivity/hyperactivity (i.e., the combined ADHD type groups and the hyperactive groups) and the control group, where once more, the first two groups showed a more significant deficit. With differences between the groups of inattentive ADHD type and hyperactive ADHD type, the changes in motor activity were remarkably close to those seen for the commission variable—notably, the groups with impulsivity/hyperactivity as the primary factor showed increased activity. The inattentive ADHD group performed slower than the control group regarding response time, which was the final difference [36].

After analyzing the variables in each of the test scenarios, it was discovered that the AULA Nesplora test was effective in differentiating between different kinds of ADHD and isolating them from a control group. Therefore, based on the information provided by this test, the results of this study may help guide professionals toward a better estimation, interpretation, and evaluation [36].

5. Discussion and Conclusions

Finally, it's important to highlight how significant and helpful digital technologies are to education. Technologies that enable and enhance educational processes, such as evaluation, intervention, and learning, include mobile devices [43-44], a variety of ICT apps [45-56], AI & STEM ROBOTICS [57-60], and games [61]. Additionally, using ICTs in conjunction with theories and models of metacognition, mindfulness, meditation, and the growth of emotional intelligence [62-73] accelerates and enhances educational practices and outcomes, particularly the processes for ADHD evaluation.

This study primarily aims to examine the literature on using video games in real-world or virtual settings to diagnose ADHD symptoms. Symptoms of ADHD in children are present. The disorder's primary signs and symptoms are inattention, hyperactivity, and impulsivity. When doing a task, memory and attention are connected, claim Angelopoulou & Drigas [41]. They play a critical role in evaluating the cognitive abilities of people with ADHD since longer attention spans are associated with better working memory levels. Additionally, working memory issues are more common in children with ADHD. Usually, medical experts determine if a kid has ADHD by looking at their parents' and instructors' responses to a questionnaire. This approach is unfavorable for accurate and sincere diagnosis since it is challenging for kids with ADHD and is prone to variable outcomes.

Instead, because the outcome of the diagnosis entirely depends on how well the children with ADHD do in the games, diagnosing using electronic games and virtual reality classrooms may be more valid. This could encourage kids to participate in the diagnosis and produce more accurate diagnostic results. Additionally, because attention deficiency is the primary symptom of ADHD, it is possible to determine if children display this attribute by employing tests that focus solely on attention levels [42]. Through brain-computer interface (BCI) devices, EEG signals can measure attention levels. This diagnostic technique records the player's EEG signal as they play using brain-computer interaction technologies and serious games.

In serious games, artificial intelligence and virtual reality may be utilized to evaluate children with ADHD. On the one hand, virtual reality produces an engaging environment that may provide a lifelike sensory experience throughout the diagnostic process. Conversely, machine learning can categorize the data gathered throughout the game and increase diagnostic precision. For a long time, there has been debate on diagnosing ADHD within the scientific community. To detect the cognitive and metacognitive deficiencies of children with ADHD and to include them as soon as feasible in a therapy setting, researchers must continually hunt for the most effective way.

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