PAPER

Intercultural Education and ADHD: The Use of Virtual Reality as a Means of Intervention and Assessment

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ABSTRACT

People are looking to the digital world for solutions to the challenges they face in their everyday lives, as technology continues to advance rapidly. People with impairments now have equal access to learning opportunities due to technological advancements. ADHD (attention deficit hyperactivity disorder) has become more prevalent among children and teenagers from ethnic minorities in recent years. Due to challenges with cognitive and metacognitive functioning, this condition is associated with various learning and behavioral difficulties. People can only assimilate into the social environment once they have developed these functions. Children can learn alternative techniques to manage their cognitive deficiencies and adapt to various contexts by developing self-awareness, self-regulation, and self-control through internal attention. With the rapid advancement of research, numerous medical and psychological approaches have been developed for the treatment of ADHD, significantly assisting in the management of symptoms. The current study examines different therapeutic strategies aimed at improving the quality of life for children from racial and ethnic minorities who are affected by ADHD. These strategies include video games with virtual reality (VR) environments.

KEYWORDS

attention deficit hyperactivity disorder (ADHD), social and emotional development, ICTs, virtual reality (VR) games, learning, metacognition, ethnic minority children, intercultural education

1 INTRODUCTION

A person who belongs to an "ethnic minority" is someone whose race, religion, language, or cultural background differs from that of the majority population [1]. This term refers to a diverse array of individuals and social groups who find themselves in various social and political situations, including historical national minorities, immigrants, migrant laborers, refugees, and asylum seekers. Cross-cultural studies in the United States show that ethnic minority children are assessed and treated for attention deficit hyperactivity disorder (ADHD) symptoms far less frequently than their non-minority counterparts [2–3]. According to European

research [4–7], immigrant children also had lower rates of ADHD diagnosis and therapy compared to non-immigrant children. Despite increasing concerns about the misdiagnosis and detrimental health impacts of ADHD within certain minority communities, several studies indicate that minority children are being over-diagnosed with neurological disorders and disabilities, and are disproportionately placed in special education [8].

Attention deficit hyperactivity disorder is one of the most common neurological disorders that affects children and adolescents. It still has a complex personality, and we only need to partially understand how it operates [9–10]. Lack of concentration and impulsivity are the main characteristics of ADHD, which are caused by a disruption in the executive functions of the brain regions that regulate specific skills, as stated in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (*DSM-5*) [11]. Executive skills, such as short-term memory, mental flexibility, and self-control, are essential for maintaining a healthy socio-emotional well-being [12]. Additionally, while cognitive ability is a well-established predictor of academic progress, a child's poor academic performance resulting from personal shortcomings contributes to low self-esteem [13]. Early development and management of these skills lay the foundation for attention, organizational skills, and ability to focus on specific tasks, mood regulation, and self-evaluation [12]. The ability to self-regulate is another aspect of emotional intelligence that is connected to ADHD in children. Emotional intelligence is the master switch for perception, thinking, cognition, problem-solving, and judgment. Additionally, it emphasizes self-regulating traits, including the capacity to tolerate irritants, delay gratification, and control impulsive actions (ego power).

Drigas and Papoutsi [14], based on their study, proposed a hierarchical and tiered strategy for the development of emotional intelligence, which illustrates how a person grows over time. This method may be applied as a therapeutic tool to address problems related to special education, social relationships, and various other aspects of life. These levels are specifically linked to understanding and recognizing emotional signals, self-awareness, self-management, empathy, social abilities, and self-actualization. According to Maslow's hierarchy of needs, the highest level of self-realization, self-fulfillment, and accomplishment is self-actualization [15–16]. The "center" of metacognitive abilities, according to a multilevel metacognition model proposed in a different study by Drigas and Mitsea [17–19], is attention. Attention participates in processes such as choosing, filtering, suspending, processing, storing, retrieval, predicting, monitoring, adjusting, adapting, recognizing, differentiating, remembering, and knowledge transformation. Each level in this paradigm represents a more advanced control system, demonstrating the subject's growth in metacognition. As one progresses from lower to higher levels of metacognition, there is a shift in self-awareness and self-observation, resulting in the development of a more intricate control system. Without having mastered these pillars of metacognition, individuals are unable to integrate the cognitive and socio-emotional skills necessary for social integration. Metacognition is an essential tool for self-knowledge, self-improvement, and self-care. It should, therefore, be the focal point of a specific intervention program that promotes comprehensive learning. Medication is recognized as the first line of treatment for reducing ADHD symptoms because it promotes metacognitive skills. However, it has a variety of disadvantages due to its adverse effects and risk of addiction. On the other hand, intervention strategies based on modern technology, such as virtual reality games, have proven to be equally effective.

2   THE CHARACTERISTIC OF DIFFERENT ETHNO-CULTURAL ORIGINS

The phenomenon of immigration is observed worldwide, and wherever it occurs, it brings about similar problems related to the integration of individuals and the acceptance of cultural and religious differences [20]. Migration refers to the voluntary or involuntary movement of individuals or groups from their country of origin to another country, where they must adjust to the new country's social, economic, political, and cultural conditions [21]. The search for more favorable living conditions, the need to find work, the improvement of the quality of life, and various family, political, and religious reasons can lead to migration [22]. Settling in a new country is associated with various social factors that influence the behavior of individuals and the groups to which they belong, as well as the social groups in the host country [23].

Various terms are used to describe culturally minority groups in the host country, such as "foreigners," "immigrants," "refugees," and "returnees" [24]. A "foreigner" is defined as any person without citizenship in the country where they reside. Those who possess the citizenship of a state are referred to as nationals of that state. Therefore, citizenship is the primary criterion for distinguishing between natives and foreigners [25]. Generally, foreigners are considered a diverse group that exhibits heterogeneity in terms of numbers, cultural elements, languages, socio-economic levels, religions, etc. It is essential to clarify that not all immigrants are considered foreigners. This is because immigrants who acquire citizenship during their stay in the host country are no longer classified as foreigners [26]. Furthermore, immigrants may possess foreign citizenship, but they acquire the nationality or origin of the state to which they relocate, as is the case with returnees. Furthermore, immigrants may acquire the nationality of the host country and choose to return to it after a period of residing in a foreign country, as is the case with "returnees" [27].

According to the 1951 Geneva Convention of the United Nations, a universally recognized term for refugee is established. A "refugee" is defined as an individual who has been forced to leave their home country and has a well-founded fear of being persecuted based on their race, religion, or nationality. At the same time, the legislative framework of his country cannot offer him protection [28].

People who belong to the nationally dominant group and those who belong to ethnic minority or immigrant groups exhibit differences in characteristics, values, and behavioral patterns [29]. The consequences of migration can have a profound and distressing impact on children and adolescents, despite the fact that the decision to relocate is often made with the intention of enhancing their quality of life. The migration flow and the arrival of foreigners in a country also affect the education system, as children and teenagers with cultural differences are invited to study in schools in the host country [20]. Besides, migration and education are interrelated concepts with many aspects [30]. However, it is essential to point out that the experiences of various minority groups and the school experiences of the children who belong to them are not identical. This is because each ethnic minority group has different cultural backgrounds and encounters different conditions in the host country [24].

The education of refugee children is a crucial aspect of the refugee issue. Recent research has shown that teachers who undertake to teach refugee children face multiple challenges and increased work stress for various reasons. These reasons include insufficient training, the heterogeneity of the students in terms of nationality, their lack of knowledge of the Greek language, diverse socio-cultural backgrounds, family difficulties, and the psycho-emotional needs of the children [31].

Teachers working in general education tend to recognize several essential benefits of inclusive education. These benefits include cultivating moral and social values, promoting the exchange of cultures, reducing prejudices, and facilitating smooth social adaptation. However, at the same time, they highlight the difficulties of implementing these institutions, such as language barriers, communication problems, reactions from the native parents, and the diverse ethnic and cultural characteristics of the refugees [32]. In general, it is essential to emphasize that providing early educational support for students belonging to ethnic minority groups reduces the risk of academic underachievement [33].

3   THE CHARACTERISTIC OF DISABILITY

There is no consensus on a universally accepted definition that accurately conveys the meaning of "disability" due to the prevalence of various theoretical concepts and the existence of a wide range of disability forms [34]. The concept of "disability" is dynamic and evolving, and it is a unique individual experience [35]. The complexity of the concept makes it difficult to clarify, which leads to the emergence of social representations towards people with disabilities. In general, disability refers to a range of conditions that limit a person's functionality in various areas, including their motor, sensory, intellectual, and emotional functions [36–37]. It is accompanied by physical or even mental difficulties that hinder the person from participating in meaningful activities in daily life [38].

4   ATTENTION DEFICIT HYPERACTIVITY DISORDER

Children with ADHD present a range of symptoms. The main features of the disorder are inattention, hyperactivity, and impulsivity. However, secondary symptoms such as aggression, antisocial behavior, impaired social skills, low self-esteem, and depression are also typically present [39].

Regarding inattention, children with ADHD find it difficult to focus their attention in situations that they perceive as dull or boring, such as repeating exercises during a lesson. They often appear to not listen when spoken to and are described as being abstracted or dreamlike [39–40]. As a result, individuals often leave activities unfinished, frequently opting to start something else or switch activities rapidly when they lose interest [41]. In addition, they need assistance in maintaining focus and following instructions until completion, which can help prevent repeated mistakes. When trying to focus their attention on an activity, individuals are sensitive to distractions, such as a loud voice or a door slamming. Furthermore, they often lose their belongings and forget their daily responsibilities. They also struggle with organizing tasks and managing their time [40, 42].

Regarding impulsivity, children with ADHD often act without considering the consequences of their actions. More specifically, they interrupt without waiting for someone to finish speaking, recklessly answer questions before they are finished, have difficulty waiting for their turn in class or a game, and need help to follow the rules [43]. Also, their reactions are unpredictable and unstable, and often it seems that they cannot control themselves [39].

Regarding hyperactivity, children with ADHD struggle to control their activity when it is necessary to remain still, for example, during a lesson in a school classroom. Also, they often need help controlling their movements and speech.

When someone asks them to be quiet, they tend to get nervous and fidget by moving their legs and arms or chattering uselessly. Because these children are constantly in motion, it is common for them to lack a proper perception of fear and become involved in various dangerous situations that put them at risk of accidents [44].

Many children with ADHD have significant difficulties forming friendships, likely due to their aggressive and disruptive behavior. As a result, they are often marginalized and experience rejection and indifference from others. Although they are usually friendly and social, most of the time they misinterpret the social signals they receive, leading to a misunderstanding of their peers' attitudes and intentions [45]. Finally, their symptoms affect the quality of their relationships and communication with their family.

5 THE COEXISTENCE OF THE CHARACTERISTICS OF DIFFERENT ETHNO-CULTURAL ORIGINS AND DISABILITY

International students with disabilities are a unique group of children within the school [38]. They are not considered a homogeneous group, as students with various forms of disabilities or students from different countries are included. Thus, complex differences occur both between groups (e.g., in terms of culture, religion, language, and abilities) and between individuals within the same group (in terms of character, temperament, health, and subjective perceptions). These differences contribute to the heterogeneity of the student population observed in schools [46]. In addition to these complex characteristics, other individual differences such as age, sex, socio-economic level, type of disability, and severity of disability are commonly observed.

People with cultural peculiarities and disabilities face significant challenges when adapting to a new country. In particular, they are asked to cope with linguistic and cultural difficulties, acculturation stress, and discriminatory attitudes they may experience in the new country, as well as the obstacles caused by their disability status [38]. Therefore, it is understandable that foreigners with disabilities face increased challenges, as they must navigate both the additional psychological, social, and economic burdens of immigration and the difficulties of accessibility [47]. Moreover, these individuals usually have limited financial resources and face various obstacles related to the structure and processes of the social system [38]. Students with disabilities from diverse ethno-cultural and racial backgrounds also face unique and heightened academic challenges [48]. In particular, factors such as the influence of the mother tongue on language learning in the host country, as well as the cognitive demands of educational tasks (such as reading and comprehension in the host country's language), often contribute to the poor academic performance of these students [49]. Until today, the educational measures or actions proposed and implemented for international students with disabilities have focused on one of two factors of otherness—either their different national origin or their disability -status—without ensuring comprehensive educational benefits that address the full range of needs and unique characteristics of students belonging to this vulnerable social group.

It is essential to point out that not all students from this minority group have the same experiences in school. Due to the heterogeneity of the population in terms of country of origin or disability, some children may experience exclusion or marginalization more frequently. This can manifest in various ways, such as feeling silenced, being ashamed of their ethnicity or diversity in general, or facing stereotypes based on their skin color. In general, it is necessary to further explore aspects of otherness that contribute to a more comprehensive understanding of students who belong to multiple minority groups and fall outside the boundaries of the "typical" [46].

6 VIRTUAL REALITY GAMES AND INTERVENTION

Yanguas et al. [50] utilized VR to develop a video game called "The Secret Trail of Moon" (TSTM), which featured a gamified version of chess. Despite its straightforward rules, chess requires a high level of cognitive abilities, including attention, executive function, and memory [51–52]. The goal of TSTM was to provide a unique and motivating tool for the cognitive treatment of patients with ADHD. There are six labor zones in this video game. Each area—attention, working memory, planning, spatial ability, impulse control, and reasoning—is intended to help individuals with ADHD in a specific area of impairment. Chess is a unique strategy game that serves as a primary component in video games. Chess occurs in TSTM in three different variations: A) As a workspace with chess tutorials and practice games; B) As the main topic of the workspace, where the chessboard's components and its pieces are used for cognitive exercises without requiring knowledge of the game's rules. For instance, the player must be careful to press the X button on the game controller whenever the "pawn-horse" sequence appears in the "Smasher" game; C) In the storyline of the video game. As an illustration, the player may find themselves in a forest where chess pieces narrate the story of a unique planet. He will learn more about the connection between the forest and chess as he travels with the creatures that accompany him. Playing a game of chess against the AI is the true test of the video game.

A user-oriented methodology was used to modify the initial design of the video game [53]. Patients who had experience with multiple video game versions provided input to the researchers during the usability testing. According to the patients' demands and preferences, they were able to enhance the layout of the game with the help of this input. The video game was created with the assistance of Sony PlayStation VR and the Unity Game Engine. In the trial, 105 individuals with a diagnosis of ADHD who were also taking regular medication were randomly assigned to three groups: the control group, the online chess therapy group, and the TSTM group. Before and after the operation, all patients and their parents underwent evaluation. The 12-week training period. In contrast to patients who do not participate in any interventions (control group), it was hypothesized that patients trained in TSTM or online chess would show improved executive functioning.

The findings demonstrated that TSTM was entertaining, clear, easy to use, and visually appealing, resulting in satisfactory engagement from the majority of participants. Additionally, compared to the online chess intervention group or the control group, the patients in the TSTM intervention group showed greater improvement in their executive functions and exhibited fewer undesired behaviors [50].

In children with ADHD, as an intervention method for improving attention, abstract thinking, and complex information processing VR games were used by Yang-Kun et al. [54]. There are two phases to this study. In the first step, semistructured interviews were conducted with physiotherapists and psychotherapists to gain an understanding of the treatments for children with ADHD and to assess the challenges involved. This was done in order to create recommendations for the selection of games. In the second stage, a three-month, three-times-per-week training program was developed for children with ADHD using the virtual reality gaming device HTC VIVE (HTC, Taiwan). Three children, aged 8 to 12 years, with ADHD but no other conditions or issues and no previous experience with VR-based training, were recruited for the study.

Each child's parents were present throughout the sessions but did not participate in the activity. Three specially designed games with different levels of difficulty were used in the experiment to assess the participants' ability to synchronize visual and

motor skills. Four assessments were used to evaluate participants both before and after each session: [55], the attention test for primary school children (ATESC), a tool created in Taiwan by Lin and Chou [56], the Wisconsin Card Sorting Test (WCST), and the Chinese version of the revised Swanson, Nolan, and Pelham (SNAP-IV) [57] were the first four non-verbal intelligence assessments.

The degree of difficulty increased from beginner to advanced throughout each three-week cycle. Each youngster selected the game they would play during the sessions over the past three weeks. Before and during this program, the researchers compared the children's attention, abstract thinking, logic, and complex information processing. The results indicated that the hyperactivity/impulsivity, attention span, and reduction in provocative behaviors in the children with ADHD had all improved. The TONI-4 assessment results showed that Participant A improved his score from 78 to 87 in terms of intelligence, cognitive function, and critical thinking. Participant B maintained his score of 84, while Participant C made the most progress, increasing his score from 65 to 83. After the trial, participants' scores improved overall. The results of the ATESC revealed that the participants' scores in the five attention exercises significantly increased following the experiment. While the other two participants displayed decreased performance, one individual demonstrated an improvement in abstract thinking and information processing. Participants B and C did not improve their performance in this area, but Participant A made fewer persistent mistakes [54].

In their study, Bland'on Diego et al. [58] evaluated and trained children with ADHD in attention and self-regulation using the virtual reality 3D video game Harvest Challenge. Using a brain-computer interface system (MindWave BCI), attention levels were mapped from 0 to 100% by inserting an electrode into the frontal lobe. EEG signals were also captured while the subject was at rest. Due to their ability to foster strong desire, neurofeedback treatments and interactive games are excellent therapeutic options for reducing the symptoms of the disorder [59].

Nine children, aged 5 to 12, who were diagnosed with ADHD participated in two intervention sessions at a local specialist facility. Two phases of the 30-minute sessions were used: the first phase lasted 5 minutes, and the second phase lasted 25 minutes. The young participant was observed in the initial phase while listening to smoothing music, music and their EEG signals were collected by the MindWave device using the OpenViBE open-source software. Three distinct levels of interaction were created during the second phase:

1. Equipment: Adventure sports are available at the game's opening on an ecological farm. The player's initial objective is to gather the necessary gear for a safe trip, which requires a significant increase in concentration (more than 50%) and adherence to the regulations. The visual cues they see on the screen must be used to select a helmet, a pair of gloves, a rope, and footwear.
2. Path repair: The player must climb a mountain to obtain the rope. Due to this, a set of wooden steps was built on a lengthy path where some accidents had occurred. Players will, therefore, need to pay more attention if they want to fix the track.
3. Carrot harvest: Participants interact with computer-generated items during this stage. The user's attention levels are raised and maintained by placing them in a large field of carrot harvest and providing them with a basket to pick as many carrots as they can. If players become less focused, the carrots disappear below the surface and become impossible to harvest. After the time limit (30 minutes) has passed, the video game is over [58].

According to the findings, children who played the video game Harvest Challenge performed better, indicating an improved capacity for sustained attention and self-control [58]. Additionally, the findings revealed increased activity in alpha and beta waves, which are frequently linked to hyperactivity [60].

7   VIRTUAL REALITY GAMES AND ASSESSMENT

Yantong et al.'s study [61] aimed to determine if VR-based tests could be used to diagnose learning deficits in school-aged children with ADHD. According to multiple studies, the use of virtual reality-based diagnostic tools is a major breakthrough in diagnosing ADHD. This is primarily due to its ability to facilitate realistic comparisons between control and ADHD groups [62]. More precisely, Drigas and Mitsea [18] found that these settings could identify signs of inattention, distraction, and hyperactivity in their research on the impact of virtual reality on children with impairments.

By comparing 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 to 18. The children in the ADHD group were identified as having ADHD using the DSM-V diagnostic criteria [11]. The VR exam was conducted using equipment from the virtual reality medical center (VRMC). 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 was used to measure the overall runtime performance. This gadget features a brain-interface system that resembles a video game, multiple sensors, position detectors, and a data gathering system to facilitate statistical analysis. The VRMC method for assessing ADHD consists of three scenes: position monitoring (30 items), stroop (41 items), and object identification (60 items). It takes 20 minutes to complete the entire exam. The test findings are illustrated by the use of four indicators:

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

The study aimed to assess the ability of participants (aged six and older) to maintain attention and control when exposed to a variety of multisensory stimuli, including auditory and visual cues. This was done using the IVA-CPT test. Scales for auditory 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) for ages 6–18 [61].

The results of the comparative research showed no significant differences in age or gender between the ADHD and control groups. The parameters related to accuracy and correct responses were significantly lower in children with ADHD compared to the control group. Children with ADHD also took much longer than those without ADHD to complete tasks. The VR exam's incorrect responses were positively correlated with the CPRS hyperactivity score. In a previous study, Gilboa et al. [63] discovered a relationship between outcomes of the CPRS-R (conners' parent rating scales—revised: short) and assessment criteria for VR in children 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 the errors in the VR test and the evaluations in the CBCL 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 level of visual and auditory attention measured by the integrated visual and auditory continuous performance test (IVA-CPT). The authors concluded that a VR test could identify symptoms of ADHD, potentially making it a valuable additional diagnostic tool [61].

Neguţ et al. [64] compared the analog CPT (computerized continuous performance test) with a virtual classroom environment to assess children with ADHD. In the CPT, a type of assessment, participants must select a response to a specific auditory or visual stimulus delivered at predetermined intervals. For the objective evaluation of children with ADHD, several CPTs have been developed, including 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 [65]. 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 children (from both groups) underwent an evaluation using ClinicaVR: Classroom-CPT, while the other half underwent a standard CPT evaluation.

The cognitive assessment system [66–67] evaluated the participants' overall cognitive functioning. The Raven Standard Progressive Matrices Plus Romanian version evaluated the participants' IQ. Additionally, a 15-item customized measure for children was developed to assess their experience with Clinica VR. Participants were asked to rate their experience on a scale of 1 to 5, depending on whether they had undergone classroom CPT or regular CPT. (For instance, while I was playing on the computer, time seemed to fly by.)

The participants in the ClinicaVR Classroom must respond as quickly as possible while refraining from engaging in undesirable behaviors, all while being exposed to stimuli for an extended period of time. The virtual classroom is a rectangular space that includes desks, a blackboard, doors, windows on either side, students, or an instructor. With 3D headsets, headphones, and glasses, the students were fully immersed in the classroom environment. In the game, each player is seated at their 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 come in three different forms: acoustic (such as the sound of a bus, a door knock, footsteps, or a school bell), optical (such as a paper falling, an airplane flying by, or a teacher looking at her watch), and mixed (such as a person walking into the classroom while the door opens) [64].

The neuropsychological tests were administered to the children initially, and they were subsequently assessed using either the ClinicaVR: classroom-CPT or the conventional CPT. The average stimulus-response time, number of replies, execution mistakes, and omission errors were assessed after this procedure, which took approximately two hours. Higher ratings indicated a higher level of ease of use, absorption, focused attention, delight, curiosity, and enjoyment [64].

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. In line with the findings of the standard CPT, individuals with ADHD provided more incorrect responses in the ClinicaVR: Classroom-CPT compared to 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 increase in the symptoms of inattention in individuals with ADHD [64].

Three types of ADHD pupils (inattention type, impulsive type, and mixed type), as well as a control group, were used as the subjects of a study conducted by Areces et al. [68]. The study aimed to compare the effects of 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 [69]. This study utilized a clinical sample of 90 boys and 27 girls, ranging in age from 5 to 16. The individuals were divided into groups based on their level of ADHD, using the *Diagnostic and Statistical Manual of Mental Disorders* [11]. They were divided into four groups: the control group, the group with inattentive ADHD, the group with impulsive ADHD, and the group with combined ADHD. The families completed the ADHD Assessment Scale [70], and Wechsler's WISC-IV scale [71] was used to determine the total IQ (TIQ).

AULA Nesplora is the main area of study [72]. Participants in this exam range in age from 6 to 16, and their attention, impulsivity, sensory processing speed, and motor activity are measured. The test is conducted in VR while wearing 3D motion-detecting headset glasses and headphones (head-mounted display, or HMD). The participant pretends to be a student seated at a desk in the classroom, focusing on the blackboard. Sensors pick up every head movement with the glasses. As a result, the application alters the participant's point of view, giving the impression that they are in a virtual classroom. Three sections make up the test, and a virtual instructor gradually explains each one. For instance, the first stage is to fully immerse the user in the virtual reality environment so that they can visually locate and pop balloons [68].

The characteristics determined by the test above are equivalent to those of conventional CPTs in terms of attention deficit and hyperactivity/impulsivity. The following variables will be evaluated in further detail:

1. Omissions: This error occurs when a person should have responded to a target stimulus but does not. This statistic measures the level of focus and selectivity of your attention.
2. Commissions occur when a user clicks a button, even if the intended stimulus has not yet occurred. This action is associated with a feeling of losing control and being suspended.
3. Average response time is an assessment of processing speed, measured in milliseconds (reaction time).
4. Motor activity: The frequency and appropriateness of head movements are noted, distinguishing between necessary and superfluous motions.

There were variations between the control group and the groups with ADHD, as 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 exhibited impulsivity and hyperactivity traits (i.e., the combined ADHD type groups and the hyperactive groups) and the control group. Once again, 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 similar to those observed for the commission variable. Notably, the

groups with impulsivity or hyperactivity as the primary factor exhibited increased activity. The group with inattentive ADHD performed slower than the control group in terms of response time, which was the main distinction [68].

After analyzing the variables in each of the test scenarios, it was discovered that the AULA Nesplora test was effective in differentiating between various types of ADHD and distinguishing them from a control group. Therefore, based on the information provided by this test, the results of this study may help professionals by guiding them towards a more accurate estimation, interpretation, and evaluation [68].

8 DISCUSSION AND CONCLUSIONS

Finally, we emphasize the importance of digital technologies in the field of education and in ADHD training. These technologies are highly effective and productive, as they facilitate and enhance assessment, intervention, and educational procedures. They can be accessed through mobile devices, allowing educational activities to be carried out anywhere [87–88]. Additionally, various ICT applications play a crucial role in supporting education [89–90]. Furthermore, educational games have the potential to significantly improve educational procedures, reaching new levels of performance [58, 76, 81]. Additionally, the integration and utilization of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation [78, 91–94] have been shown to enhance educational practices and outcomes, especially for minority children with ADHD. This approach encompasses various domains, including assessment and intervention.

More specifically, current statistics show that a significant portion of the population is now multicultural. The development of therapy materials, practice models, evaluation techniques, and client collaboration are all, to a great extent, influenced by culture. The relationship between a client and a therapist is also discussed in recent writings, as is the significance of understanding a child's needs within the context of their culture. Ethnic minority youths and teens still lag behind their non-minority counterparts in terms of evaluation and therapy rates, despite significant advancements in the development and implementation of effective programs for children with attention deficit hyperactivity disorder.

Children with ADHD are increasingly being diagnosed and treated using video games and other cutting-edge technology [73–75]. When playing video games, it is essential to utilize executive, organizational, and metacognitive skills [76–78]. Memory and focus are the two abilities most commonly utilized in games. Memory and attention are intertwined while performing a task [79–82]. Since longer attention spans are linked to higher levels of working memory, they are essential for the cognitive functioning of individuals with ADHD [83–84].

Serious games are poised to play a significant role in treatments, especially in the treatment and monitoring of ADHD symptoms, thanks to VR settings created by new technology [84]. Drigas and Mitsea [78] concluded that VR environments could potentially alleviate symptoms of inattention, distraction, and hyperactivity. Their study focused on the effects of hypnosis through virtual reality on children with impairments. Additionally, VR settings nurture a variety of executive functions, improve emotional control, and enhance participant reactions [84].

It is crucial to always hold the attention of children with ADHD, as they tend to grow bored quickly. This is made possible by video games, as they keep kids engaged and focused throughout the entire time while also demanding that they be fully alert and aware of their surroundings [82]. According to the findings of the current bibliographic

study, virtual reality environments used in serious games have a positive impact on all aspects of social skills in children with ADHD [85]. Children's executive functioning and ADHD symptoms dramatically improve [86], and they display fewer negative behaviors [50]. Additionally, research by YangKun et al. [54] suggests that serious games can improve various aspects of children with ADHD's performance, including attention, hyperactivity/impulsivity, critical thinking, abstract reasoning, and information processing. The debate over the etiology of ADHD and the available treatment options for children from ethnolinguistic minorities highlights the rapid development in these fields of study. In order to enhance the cognitive and metacognitive abilities of these children and enable them to integrate into the social world, further study is required to develop alternative therapies using serious games in virtual reality settings.

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