Artificial Intelligence in ADHD treatment: a brief narrative review

Alessandro Frolli[1], Emilio Saviano[2], MariaCarla Ricci[3], Simona Luigia Sica[4], Marco Romano[1]

[1] *Department of International Humanities and Social Sciences, Rome University of International Studies, Rome (Italy)*
[2] *Healt Psychology and Science Communication, San Raffaele Telematic University of Rome, Rome (Italy)*
[3] *Fondazione Italiana Neuroscienze e Disordini dello Sviluppo, Caserta (Italy)*
[4] *Department of Humanities, University of Naples "Federico II", Napoli, (Italy)*

Abstract

Artificial intelligence (AI) is revolutionizing the treatment of Attention Deficit Hyperactivity Disorder (ADHD) through more precise diagnoses and personalized therapies. AI-based cognitive training programs utilize technologies such as augmented reality (AR) and virtual reality (VR) to enhance executive functions in children with ADHD, offering interactive and personalized exercises that stimulate attention and impulse control. These programs, including CogniFit, BrainBeat, NeuroPlus, and Lumosity, integrate real-time feedback and continuous monitoring, increasing motivation and treatment effectiveness. AI supports early diagnosis by analyzing data from neuropsychological, behavioral, and neurophysiological tests, identifying complex patterns associated with ADHD. Examples of diagnostic tools include QbTest, Adeo, NeuroElectrics, Mindstrong Health, and Cortica. However, despite promising results, it is necessary to scientifically validate these approaches and address challenges related to accessibility and data privacy protection. In conclusion, AI represents an innovative frontier in ADHD treatment, significantly improving patients' quality of life through personalized therapies and dynamic monitoring.

Keywords

ADHD, IA, Virtual Reality, Serious Games, Attention, Adolescents, Children, eHealt

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that profoundly impacts the lives of children and adults worldwide. This disorder is characterized by a persistent pattern of inattention, hyperactivity, and impulsivity, which significantly impairs the adaptive and daily functioning of affected individuals [1]. ADHD not only affects concentration and motor behavior but also involves deficits in executive functions, emotion regulation and modulation, and motivation [2]. These symptoms make it difficult for individuals with ADHD to manage the demands of school, work, and social life. The use of artificial intelligence (AI) for individuals diagnosed with ADHD represents an area of growing interest and innovation. AI offers numerous applications ranging from early diagnosis to the management and treatment of the disorder, providing personalized and efficient solutions [3]. In this brief review, we aim to introduce and support the use of artificial intelligence for the diagnosis and treatment of ADHD. The history of AI in the treatment of ADHD is recent but rapidly evolving, combining

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alessandro.frolli@unint.eu (A. Frolli); emilio.saviano@uniroma5.it (E. Saviano); mariacarla.ricci1@gmail.com (M.C. Ricci); lusisica@unina.it (L.S. Sica);); marco.romano@unint.eu (M. Romano);
0000-0002-2784-2887(A. Frolli); 0009-0006-6553-702X(E.Saviano); 0000-0001-5712-2939 (M.C. Ricci); 0000- 0001-5587-8097 (L. Sica); 0000-0002-8581-3160 (M. Romano);

advanced technologies with innovative therapeutic approaches to improve the diagnosis, treatment, and monitoring of this disorder. Since the 2000s, eHealth has begun to be used in clinical settings for various disorders [4]. The initial applications mainly involved diagnostic support tools based on machine learning algorithms that analyzed behavioral and
neuropsychological data to identify patterns associated with ADHD [5]. With the advancement of machine learning and deep learning technologies [6], the algorithms have become more sophisticated, allowing for greater accuracy in diagnosing and predicting ADHD symptoms. Natural language processing (NLP) techniques and the analysis of large behavioral datasets are being used to better understand patterns of attention and hyperactivity.

2. Mobile and Wearable Applications

The increase in the use of mobile and wearable devices has opened up possibilities for the continuous monitoring of ADHD symptoms. AI-based mobile applications can monitor user behavior and provide real-time feedback [7], while wearable devices collect physiological and behavioral data for analysis [8]. Mobile applications and wearable devices represent one of the most promising frontiers in the treatment of Attention Deficit Hyperactivity Disorder (ADHD). These tools combine the power of artificial intelligence with the practicality and pervasiveness of mobile technologies to offer innovative solutions in monitoring, diagnosing, and treating ADHD [9;10;11]. By examining these technologies more closely, we describe some features of these Intelligent Tools (IT):

***Behavioral Monitoring and Data Collection**:* Mobile applications for ADHD treatment often include behavioral monitoring features. These applications can record various aspects of a patient's daily behavior, such as physical activity levels, sleep patterns, and phone usage. The collected data is analyzed using machine learning algorithms to identify patterns and provide real-time feedback to both patients and doctors. For example, apps like Parenting Management allow parents to monitor their children's behavior, recording instances of inattention or hyperactivity and providing advice on how to manage them [12].

***Games and Cognitive Training**:* Many mobile applications use games and cognitive training activities designed to improve executive functions such as attention, working memory, and impulse control [13;14]. These games are often personalized using AI to adapt to the child's skill level and provide appropriate challenges. An example is Akili Interactive's EndeavorRx, a therapeutic video game approved by the FDA for the treatment of ADHD in children [15]. The game uses attention and multitasking tasks to enhance the cognitive abilities of children with ADHD.

***Personalized Treatment Plans**:* Applications can also provide personalized treatment plans based on the collected data. By analyzing behavioral data, these applications can suggest specific interventions and adapt treatment strategies to the individual needs of the patient. For instance, MyADHD is an application that offers tools for symptom monitoring and treatment management, allowing patients, parents, and doctors to collaborate effectively [16].

Support for Behavioral Therapy: Some mobile applications are designed to support cognitive-behavioral therapy (CBT) [17]. These applications can provide exercises, reminders, and feedback to help patients develop coping skills and better manage ADHD symptoms. CBT-i Coach is an example of an app that, although originally developed for insomnia, has been adapted to include modules that help manage ADHD, offering relaxation techniques and problem-solving strategies.

***Physiological Monitoring**:* Wearable devices, such as smartwatches and fitness trackers, can constantly monitor physiological parameters like heart rate, physical activity levels, and sleep patterns. This data is crucial for better understanding the patient's behavior and the factors influencing ADHD symptoms [18]. For example, the Mente Autism Headset uses EEG sensors to monitor brain activity and provide neurofeedback, which can help improve attention [19].

Biofeedback and Neurofeedback: Some wearable devices are designed to provide real-time biofeedback or neurofeedback. These tools can help patients develop greater control over their physiological and behavioral responses [20]. Muse is a headband device that uses EEG sensors to monitor brain activity and provide feedback during guided meditation sessions, helping patients improve concentration and reduce stress.

Reminders and Alerts: Smartwatches can be programmed to provide reminders and alerts that help patients with ADHD stay organized and follow daily routines. Features like medication reminders, schoolwork completion prompts, or scheduled activity participation can be extremely helpful. For instance, Apple Watches can be configured with personalized reminders to support the daily management of ADHD symptoms [21].

Applications Specific to Wearable Devices: Some applications are designed specifically for wearable devices, leveraging the unique capabilities of these devices. For example, the Focus@Will app uses music and sound to enhance concentration and productivity [22] and is compatible with various wearable devices to provide a personalized experience.

3. AR and VR-Based Cognitive Training Programs

Several platforms offer AI-based cognitive training programs to improve executive functions in children [23; 24]. These programs include games and activities designed to stimulate specific brain areas associated with attention and impulse control. AI-based cognitive training programs are emerging as effective tools in the treatment of Attention Deficit Hyperactivity Disorder (ADHD). These programs aim to enhance the executive functions and cognitive abilities of patients through interactive and personalized exercises. In this context, AR and VR technologies have begun to be integrated into ADHD treatments [25], providing immersive environments for attention and self-control exercises [26]. VR allows for the creation of highly controlled and personalized environments where patients can be exposed to specific scenarios designed to improve certain cognitive and behavioral skills. These environments can simulate real-life situations, such as a classroom or home setting, offering a safe and risk-free context for practice and learning [27]. VR also enables the simulation of real-life situations that patients may find difficult to manage. For example, a patient can be exposed to a virtual classroom environment to practice attention and behavior management techniques. This simulation provides a unique opportunity to practice in a realistic yet controlled setting.

Initial Diagnosis and Assessment: Cognitive training programs often start with a diagnosis and assessment phase, during which data on the patient's cognitive and behavioral functioning is collected [28]. This phase may include neuropsychological tests, questionnaires, and clinical observations. AI analyzes this data to identify areas of weakness and specific patient needs.

Program Personalization: One of the main features of AI-based cognitive training programs is their ability to personalize [29]. Using machine learning algorithms, the program continuously adapts exercises and activities based on the patient's progress and responses. This approach ensures that the training is always tailored to individual needs.

Interactive Exercises and Gamification: The proposed exercises are often presented as interactive games, making the training more engaging and motivating for children. These games are designed to stimulate specific cognitive functions, such as sustained attention, working memory, impulse control, and planning ability. Gamification increases motivation and adherence to the program [30].

Feedback: AI-based programs offer immediate feedback on the patient's progress, allowing dynamic adjustment of activities. Continuous monitoring enables tracking of improvements over time and identification of areas needing further attention.

Integration with Traditional Therapies: Many cognitive training programs are designed to be used in combination with traditional therapies, such as cognitive-behavioral therapy (CBT) or pharmacological therapy [31]. Integrating different treatment methodologies can enhance the overall effectiveness of the therapy, granting a more impactful intervention.

Examples of AI-Based Cognitive Training Programs (see Tab.1):

1. CogniFit: CogniFit offers a range of AI-based cognitive training programs aimed at improving various cognitive functions. CogniFit's games and activities are designed to be fun and engaging, and patient progress is continuously monitored to adjust the difficulty level.
2. Cognifit VR: Cognifit has developed a series of VR-based cognitive training exercises designed to improve specific cognitive functions in patients with ADHD. The exercises include interactive games that challenge working memory, sustained attention, and planning skills.
3. BrainBeat: BrainBeat is a cognitive training program based on rhythms and music, designed to improve attention and impulse control. It uses real-time feedback technologies to help children develop sustained attention and synchronization skills [32].
4. NeuroPlus: NeuroPlus combines neurofeedback, cognitive training, and interactive games to improve executive functions in children with ADHD. It uses EEG sensors to monitor brain activity and provide immediate feedback, helping children improve self-regulation and attention [33].
5. Lumosity: Lumosity [34] is a brain training application offering a wide range of games designed to improve memory, attention, mental flexibility, and other cognitive functions. Although not specifically developed for ADHD, many parents and therapists use it as a complementary support in ADHD treatment.
6. Virtually Better: Virtually Better develops VR applications for the treatment of various psychological disorders, including ADHD. Their applications use immersive environments to provide personalized cognitive and behavioral training.
7. Mightier: Mightier uses biofeedback games to help children improve emotional control and stress management [35]. Children wear a sensor that measures heart rate, and the game adjusts in real-time to help the child practice relaxation techniques.

Table.1
AI-Based Cognitive Training Programs

App	Program	Device
Cognifit	Contextualized Memory; Motor Coordination; Planning; Working Memory;	Smartphone; PC; Tablet
Cognifit VR	Contextualized Memory; Motor Coordination; Planning; Working Memory;	Virtual Reality Headset
BrainBeat	Attention; Behavioral Regulation; Coordination	Arm Sensor; Metronome; Headphones
NeuroPlus	Attention; Self Regulation	Smartphone; PC; Tablet
Lumosity	Memory; Attention; Cognitive Flexibility	Smartphone; PC; Tablet

Mightier	Planning; Attention; Working Memory; Behavioral Regulation;	Arm Sensor;Smartphone; PC; Tablet

The benefits of these programs include the ability to customize the program to the individual's specific needs, accessibility to resources (especially free apps), maintaining the effectiveness of the training program over time thanks to its ability to adapt based on the subject's responses, the motivation that immersive environments can elicit, and the ability to analyze large amounts of data [36]. This is made possible by machine learning algorithms that analyze patient data to personalize and adapt the training, and by natural language processing (NLP) systems.

4. Early Diagnosis and Personalized Treatment

AI is emerging as a powerful and innovative tool to support the early diagnosis of ADHD, thanks to its ability to analyze large amounts of data and identify complex patterns [37]. AI can integrate and analyze data from various sources, including standardized tools such as the Conners' Rating Scale or the Achenbach System of Empirically Based Assessment (ASEBA); behavioral data, collected through direct observation or video recordings; neuropsychological data; neurophysiological data such as EEG and electrocardiogram (ECG) readings; and information about the patient's genetic heritage [38]. Integrating these data allows AI to provide a comprehensive and detailed view of the patient, improving diagnostic accuracy. Machine learning algorithms are trained on large datasets to identify patterns associated with ADHD [39]. These algorithms can recognize combinations of symptoms and behaviors that might not be evident through traditional clinical observation. Some of the methods used include: (a) *Artificial Neural Networks*: Models that mimic the functioning of the human brain and can recognize complex patterns in data [40]; (b) *Random Forests:* Algorithms that use a combination of decision trees to improve predictive accuracy; (c) *Support Vector Machines (SVM)*: Techniques that find the optimal boundary between different classes of data to classify patients [41].

Examples of AI Applications in Early ADHD Diagnosis (see Tab.2):

QbTest: The QbTest [42] is a diagnostic system that combines continuous performance testing (CPT) with motion analysis. It uses AI to compare patient data with a reference database and provides an objective assessment of symptoms related to attention, impulsivity, and hyperactivity. This test is used for both diagnosis and monitoring treatment effectiveness.

Adeo: Adeo is a mobile application that uses machine learning to analyze responses to behavioral questionnaires and data from wearable sensors. The app provides an initial assessment of the risk of ADHD and suggests possible interventions. It is designed for use by parents and teachers to monitor at-risk children.

NeuroElectrics: NeuroElectrics develops portable EEG devices that can be used to monitor brain activity [43]. The data collected is analyzed by AI algorithms to identify patterns associated with ADHD. These devices are used for both early diagnosis and continuous monitoring of patients.

*Mindstrong Health:*Mindstrong Health uses AI to analyze behavioral data collected through smartphone use, such as typing patterns and app usage [44]. The algorithms can identify changes in behaviors that might indicate the presence of ADHD or other mental disorders. This technology offers a non-invasive solution for continuous symptom monitoring.

*Cortica:*Cortica uses a combination of neuroimaging, genetics, and behavioral data to diagnose and treat ADHD. AI analyzes these data to provide a comprehensive and personalized diagnostic assessment, identifying ADHD subtypes and suggesting specific treatments.

These AI applications enable early and accurate diagnosis of ADHD by integrating and analyzing diverse data sources, thus offering a personalized approach to treatment. The use of AI in

ADHD diagnosis and treatment represents a significant advancement in providing tailored and effective care for patients.

Table 2

App	Aim	Device
QbTest	ADHD diagnosis through online questionnaire	Smartphone; PC; Tablet
NeuroElectrics	Treatment Protocol	EEG; Transcranial Electrical Stimulation
MindstrongHealt	Detect biometric informations due the use of smatphone to make early diagnosis	Smartphone
Cortica	Treatment Protocol	EEG; Cranial Electrotherapy Stimulation Device

5. Benefits of Using Artificial Intelligence in the Treatment of ADHD

AI can enhance the diagnosis and assessment of ADHD through the analysis of large volumes of clinical data. Machine learning algorithms can identify patterns in behaviors and cognitive tests that may not be evident to humans [45]. AI can help create personalized treatment plans. By analyzing individual data, algorithms can suggest specific interventions and continuously monitor the patient's progress. AI applications, such as wearable devices and mobile apps, can provide continuous monitoring and real-time feedback. This can help patients better manage ADHD symptoms in their daily lives [46]. AI can reduce clinical bias in diagnoses and treatments, offering a more objective assessment based on data rather than subjective impressions [47;48:49].

5.1. Limitations of Using Artificial Intelligence in the Treatment of ADHD

The effectiveness of AI algorithms depends on the quality and quantity of available data. Incomplete or low-quality data can lead to incorrect diagnoses or ineffective treatments [50].The collection and processing of sensitive data raise concerns about privacy and security. Patient data must be protected from unauthorized access and potential breaches [51]. AI algorithms can be seen as "black boxes," where the decision-making process is not transparent. This can make it difficult for doctors and patients to understand and trust the recommendations provided by AI. Excessive reliance on AI can lead to a reduction in traditional clinical skills. It is important to maintain a balance between the use of AI and human diagnostic and therapeutic skills [52]. Not all patients have equal access to advanced technologies. Socioeconomic disparities can limit access to AI, exacerbating inequalities in mental health care [53]. One major limitation is the requirement for large, labeled datasets, which can be difficult to obtain. Early-stage research often suffers from diagnostic ambiguity and small sample sizes, which can hinder the training and validation of AI models. The complexity of ADHD as a disorder, involving both behavioral and neurophysiological aspects, presents a challenge for AI models. While models like CNNs can analyze neurophysiological data, they are sensitive to training data specifics and require intricate preprocessing, which can introduce bias or loss of critical information [54]. Translating AI-driven insights into clinically actionable treatment strategies

remains a challenge. Although AI can identify patterns and biomarkers, integrating these findings into practical, everyday treatment for ADHD requires further research and validation [55].

6. Conclusions

In conclusion, AI is revolutionizing the treatment of ADHD through more precise diagnoses [56], personalized therapies, and continuous monitoring, promising to significantly improve the quality of life for people affected by this disorder. AI-based cognitive training programs represent an innovative frontier in ADHD treatment, offering new opportunities to enhance the cognitive abilities and executive functions of patients. However, it is essential to address challenges related to efficacy, accessibility, and data protection to ensure that these tools can be used effectively and safely. With continued technological progress and greater integration of AI technologies, the future of ADHD treatment with cognitive training programs looks promising.

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