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Can AI pave the way for the Treatment of Neurodevelopmental Disorders: Current Trends and Future Prospects

Ummara Mumtaz[1], Awais Ahmed[2], Aimen Noor[3], Summaya Mumtaz[1]*

[1]Department of Information Technology, University of the Cumberlands, Kentucky, United States of America.

[2]Department of Gynecology and Obstetrics, University of Concepción, Concepción, Chile.

[3]Mayo University Hospital, Castlebar, Ireland.

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***Correspondence:** Ummara Mumtaz, Department of Information Technology, University of the Cumberlands, Kentucky, United States of America.*

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ABSTRACT

This article examines the transformative role of Artificial Intelligence (AI) in mental health care, highlighting its ability to offer assistive technologies and continuous support. Beyond early detection and diagnosis of neurodevelopmental disorders, AI holds significant potential to improve patient care and treatment outcomes. The article emphasizes the use of assistive robots and AI-powered applications to address challenges of cognitive impairment and language acquisition in individuals with Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Dyslexia, and dysgraphia. We advocate for integrating technological innovation with intervention treatments, guided by a comprehensive understanding of patient needs, to enhance the quality of life for individuals with neurodevelopmental disorders. AI plays a supportive role in improving patient care, particularly in areas where traditional pharmacological approaches alone may be insufficient. Future directions emphasize the need for establishing regulatory frameworks, transparent validation processes for AI models, and sustained efforts in research and development.

Keywords: *artificial intelligence, machine learning, large language models (LLMs), robotic interventions, robot-assisted therapy (RAT), wearable sensing devices, neurodevelopmental disorders (NDD), attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), dyslexia, dysgraphia, learning disabilities*

Introduction

The complexity of mental health disorders, combined with the increasing demand for personalized patient care, highlights the importance of integrating Artificial Intelligence (AI) into mental healthcare. This article provides an overview of the current landscape of AI-powered interventions, with a particular focus on four common neurodevelopmental disorders: Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Dyslexia, and Dysgraphia. Impairments in language and speech, motor coordination, behavior regulation, memory retention, learning capacity, and other neurological functions characterize these disorders. Epidemiological data indicates that approximately 4% of children in the United States diagnosed with ADHD also have a learning disability, highlighting the complexity and overlapping nature of these conditions [1].

ADHD and ASD are a prevalent neurodevelopmental disorder that poses substantial challenges to individuals' daily functioning. Individuals with ADHD exhibit impulsive behavior and struggle to maintain attention on tasks, whereas ASD primarily impairs social communication and interaction skills. Recent advances in therapeutic interventions have broadened the scope of treatment, thereby integrating Robotic assistance in providing effective and nonpharmacological interventions for individuals with ADHD. It has offered promising avenues for enhancing affected individuals' quality of life and functional outcomes [2]. A review study conducted by Cao et al. emphasizes the role of machine learning models in investigating behavioral and neurocognitive factors for effective ADHD treatment [5]. The study identifies that existing literature reveals inconsistent findings, suggesting that a combina-

tion of cognitive, genetic, and biological factors influences ADHD. Machine learning algorithms demonstrate enhanced capabilities in detecting complex and non-linear interactions among these variables, enabling the development of personalized, effective, and reliable treatment approaches. A review study by Meneses do Rêgo AC and colleagues suggests that AI-driven systems can be trained to track patient progress, analyze behavioral changes, and adjust therapeutic interventions accordingly [6]. This adaptive approach is essential for maintaining the long-term effectiveness of treatment, given the chronic and evolving nature of ASD.

A growing body of research has demonstrated the potential of Artificial Intelligence (AI) technologies in facilitating individuals with learning disorders. According to Ahmadi & Gholipoor, these studies emphasize the need for rigorous evaluation of computer-assisted learning tools and highlight the positive impact of AI-driven interventions in enhancing reading comprehension and literacy outcomes [3]. The evidence further suggests that AI-enabled solutions significantly improve learning experiences for individuals with dyslexia and dysgraphia. A review study by Gkeka highlights the critical role of intervention strategies such as AI-powered chatbots in enhancing language outcomes for individuals with language disorders [4]. The author suggests that AI-driven tools hold significant potential to enhance the effectiveness of therapeutic interventions.

AI-assisted interventions for ADHD & ASD

This section explores the use of AI-driven robotic tools and medical sensing devices in treating ADHD and ASD, focusing on behavior analysis and enhancing communication skills. Furthermore, it emphasizes the role of AI in facilitating real-time monitoring and adaptive therapy adjustments to ensure that interventions remain responsive to the patient's evolving needs.

Difficulty sustaining attention is a fundamental problem in ADHD and ASD, as these individuals lack concentration, proper working memory, and visual attention. The study conducted by Tleubayev et al. aimed to explore the effectiveness of Robot-Assisted Therapy (RAT) for nonverbal children with severe forms of ASD and ADHD [9]. The intervention utilized a humanoid robot, NAO, engaging three children in interactive games designed to enhance social skills, attention, and communication. Overall, the findings suggest that RAT has the potential to improve social interaction, sustained attention, and engagement in children with ASD and ADHD, although individual responses varied. Amato et al. investigated the use of Socially Assistive Robotics (SAR) combined with Artificial Intelligence (AI) to enhance therapy for children with ADHD [10]. The study developed a patient-centered system using the humanoid robot, Pepper, which engaged children through tablet-based games and real-time emotion recognition. The system adapted therapeutic activities based on the child's attention and emotional state. Results showed that an 8-year-old child with ADHD demonstrated improved focus, reduced anxiety, and active participation. Group sessions with five children aged 7-10 also reported high acceptance, increased attention, and positive engagement. These studies highlight the need for personalized robot behaviors and diverse therapeutic activities to meet each child's specific needs.

Aggressive behavior is a common and complex challenge among individuals with autism, particularly in inpatient care settings. In a recent study, Imbiriba and colleagues explored the potential of using wearable biosensors combined with machine learning algorithms to predict the onset of aggressive behavior in youths with autism [7]. The study demonstrated that analyzing physiological signals in real time can provide early warning indicators of aggression prior to its occurrence. This research provides a foundation for developing adaptive intervention systems powered by artificial intelligence for a significant yet understudied segment of the autism population. Difficulties in socialization and joint attention are core deficits among children with ASD. In this regard, Voss and colleagues developed "Superpower Glass," an AI-enabled wearable intervention designed to facilitate social engagement and provide real-time feedback during social interactions for children with ASD [8]. The study examined the effectiveness of integrating this wearable device with conventional behavioral therapy, focusing on facial engagement and emotion recognition improvements. The findings provide empirical support for integrating AI-powered wearable devices in home-based interventions.

AI-assisted interventions for Dyslexia and Dysgraphia

This section examines the application of Artificial Intelligence (AI)-driven learning interventions for supporting individuals with dyslexia and dysgraphia. These AI-based tools use adaptive feedback mechanisms to improve reading fluency, writing accuracy, and comprehension skills. Individuals with dyslexia and dysgraphia struggle to connect spoken language with written symbols. Dyslexia is characterized by persistent difficulties in reading, spelling, and decoding words, while Dysgraphia primarily affects the ability to produce legible and coherent written text. Understanding the distinct yet overlapping features of these disorders is critical for developing targeted interventions.

The study by Avishka et al. [11] proposed the development of an AI-powered mobile application, The Cure, designed to assist individuals with dyslexia and dysgraphia in improving their reading and writing abilities. The application employs machine learning models for speech and handwritten character recognition, enabling personalized learning exercises. Additionally, a predictive module was integrated to evaluate the severity levels of these disorders based on users' accuracy rates and task completion times across varying levels of difficulty. The results indicated that participants diagnosed with dyslexia or dysgraphia exhibited accuracy levels ranging between 30% and 40%. Similarly, Rajapakse and colleagues introduced ALEXZA, a mobile-based assistive application to mitigate reading difficulties in individuals with dyslexia [12]. The application incorporated advanced features such as a built-in dictionary with phonetic support and a smart AI assistant to facilitate word comprehension and user navigation. User evaluation revealed a preference for displaying 5 to 10 words per segment, while the application achieved an approximate 90% accuracy rate in text detection.

Zhao et al. proposed Let AI Read First (LARF), an AI-driven reading intervention designed to support dyslexic individuals [13]. The LARF system leverages large language models (LLMs) to generate contextual annotations within the original text, employing techniques such as highlighting, bolding, and underlining critical information without altering the textual content. It enhances comprehension and facilitates information retention. An experimental evaluation was conducted with 150 participants with diagnosed or self-reported dyslexia. The results demonstrated that LARF users achieved better retrieval of details and enhanced reading comprehension compared to control intervention groups. The study by Gupta et al. proposed an AI-based handwriting analysis system to assist individuals with dysgraphia by addressing multiple writing challenges, including poor handwriting, spelling, and grammatical mistakes [14]. The proposed system integrates three machine-learning models: handwritten text recognition, spelling correction, and a grammar correction model. The experimental evaluation was conducted using the IAM handwriting dataset and a self-created dataset collected from students with learning disabilities. The system demonstrated a character error rate of 10.2% and a word error rate of 25%. The results showed that the integrated system provides valuable assistance for improving written communication skills among individuals with dysgraphia.

Discussion

AI interventions in mental healthcare are still in the research and development stage, with several challenges limiting their practical implementation. Although Robot-Assisted Therapy (RAT) shows great potential, the technology is still not included in clinical practice. Enhancing robot autonomy and adaptability requires strong collaboration between AI experts and clinical professionals for effective intervention design and evaluation. Begum and colleagues et al. evaluated the readiness of robots in ASD interventions, concluding that robotics interventions are still far from being accepted as evidence-based practice (EBP) within clinical settings [17]. This gap largely exists because most human-robot interaction (HRI) studies fail to follow rigorous clinical research designs, limiting their acceptance by clinicians and healthcare providers.

The intricate nature of neurodevelopmental disorders and the complexity of AI systems calls for their seamless integration into existing clinical workflows. Active participation of healthcare professionals in developing and training AI models would ensure that these technologies are innovative and aligned with clinical needs [6].

Dyslexia and ADHD are frequently co-occurring neurodevelopmental disorders, with comorbidity rates estimated between 25–40%. Research into their overlap reveals shared challenges in cognitive and academic functioning. However, there is limited research specifically focused on treatments and interventions for individuals with both conditions. Future studies should explore how professionals can develop and implement effective, integrated intervention programs for children with co-occurring ADHD and dyslexia [18].

A key challenge in this field is the absence of well-defined and comprehensive regulatory frameworks to guide the safe deployment of AI-driven interventions. Nevertheless, regulatory efforts are advancing, with the Food and Drug Administration (FDA) beginning to implement oversight for specific AI-enabled medical devices, including those intended for mental health care applications. Integrating these interventions with existing EHR systems is essential to support ongoing treatment and capture AI-generated feedback[15]. This interoperability would facilitate shared access to insights, promoting coordinated care among healthcare providers.

A lack of established assessment standards for AI tools in mental health makes it difficult to measure the effectiveness of AI-driven intervention treatments. There is a potential risk that poorly developed AI systems may be prematurely integrated into mental healthcare practice, leading to unintended negative consequences. The long-term effectiveness of these tools remains uninvestigated. Integrating AI into mental healthcare presents significant opportunities to improve neurodevelopmental patient outcomes. While current AI-based interventions show promising progress, their responsible and ethical implementation remains critical. Understanding existing trends, addressing knowledge gaps, and developing appropriate policies are essential for effectively integrating these solutions in healthcare[16]. By overcoming current challenges and guiding future efforts, AI can enhance the accessibility, effectiveness, and ethical delivery of mental healthcare, benefiting both individuals and communities.

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