



AI-Powered Assistive Technologies for Dyslexia: A Survey on Advancing Learning and Accessibility

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Abstract: Dyslexia is a common learning disorder that affects individuals' reading and writing skills, creating considerable obstacles in both educational and professional environments. This paper examines the role of assistive technologies in overcoming these difficulties, with a particular emphasis on AI-driven solutions. It details the development and application of an AI-based Augmentative Alternative Communication (AI-A2C) model designed to improve learning through the incorporation of personalized educational tools. The research assesses the benefits, challenges, and possible societal implications of these technologies, highlighting the critical need for accessibility and inclusivity.

Keywords: Dyslexia, Assistive Technologies, AI-A2C, Accessibility, Learning Tools, Inclusive Education.

I. INTRODUCTION

Dyslexia is a specific learning disorder that significantly impairs an individual's capacity to read, write, and spell, despite having normal intelligence and receiving appropriate educational support. This condition is linked to neurological differences, particularly in phonological processing, which complicates the ability to decode words, understand letter sound associations, and attain reading fluency. Additionally, dyslexia may affect short-term memory and organizational abilities. This disorder can impact individuals of all ages, ethnicities, and socioeconomic statuses. Although dyslexia is often diagnosed in childhood, it can continue into adulthood, affecting academic performance, career advancement, and self-esteem. Nevertheless, many individuals with dyslexia exhibit notable strengths in creativity, problem-solving, and holistic thinking, highlighting the importance of early intervention and customized support to help them realize their full potential.

II. UNDERSTANDING DYSLEXIA

A. Cognitive and Neurological Aspects Dyslexia is a neurological condition that primarily affects an individual's ability to read, spell, and sometimes write. It is often characterized by difficulties in processing written language, but it does not reflect intelligence or a lack of effort. The cognitive and neurological aspects of dyslexia involve [1].

- **Phonological Processing Issues:** People with dyslexia typically struggle with phonological awareness, the ability to recognize and manipulate sounds in spoken language. This makes decoding words (matching sounds to letters) difficult.
- **Brain Structure and Activity:** Studies using brain imaging techniques have shown that individuals with dyslexia often have differences in the brain areas involved in reading, particularly in the left hemisphere. These areas include the angular gyrus, occipitotemporal cortex, and posterior reading systems. These differences can lead to slower and less efficient processing of written text.
- **Difficulty with Working Memory:** Many individuals with dyslexia experience challenges in working memory, which is the ability to temporarily store and manipulate information. This can affect tasks such as following multi-step directions or remembering the sequence of letters in a word.
- **Visual and Auditory Processing Delays:** Some individuals with dyslexia also struggle with visual and auditory processing, which affects their ability to link visual symbols (letters) with sounds. This can result in letter or word reversals (e.g., reading "b" as "d") or difficulty distinguishing between similar sounds.



B. Challenges Faced by Individuals with Dyslexia presents a range of challenges that affect reading, writing organization, and emotional well-being [2]. These challenges are categorized as follows:

1. Reading Difficulties and Slow Reading: Dyslexic individuals may read slowly and laboriously, often struggling to decode unfamiliar words. Word Reversals and Skipping Lines: Letters or words may be seen in reverse (e.g., "was" as "saw"), or individuals may skip over words or lines while reading [3].

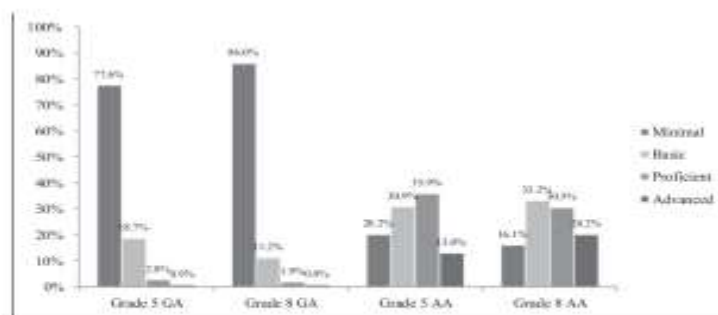


Fig. 1. Reading outcomes of students with intellectual disability on statewide assessments

2. Spelling, Writing 7 Frequent Spelling Errors: Spelling may be inconsistent, with words often spelled phonetically but incorrectly. Difficulty with Handwriting: Many individuals struggle with handwriting, which may be illegible or slow.

3. Difficulty with Time Management Issues: Challenges in keeping track of time, meeting deadlines, or organizing tasks are common. Poor Organizational Skills: Difficulty organizing thoughts and materials can affect tasks like writing essays or planning projects.

4. Mathematics Challenges and Difficulty with Word Problems: Trouble understanding and solving word problems arises due to the reading involved, even if arithmetic skills are adequate. Difficulty with Sequencing: Challenges in understanding and remembering numerical sequences or steps in math operations.

5. Emotional and Social Impacts, Frustration and Low Self-Esteem: Academic struggles can lead to frustration, anxiety, and reduced self-esteem. Social Isolation: Difficulties with reading and writing may lead to social challenges, especially in academic settings.

Recognizing the cognitive basis of dyslexia and understanding these challenges is key to providing effective support, such as using specific learning strategies, accommodations (like extended time on tests), and assistive technologies (text-to-speech tools, audiobooks). With the right support, individuals with dyslexia can thrive academically and professionally.

III. IMPORTANCE OF ASSISTIVE TECHNOLOGIES

Assistive technologies (AT) have emerged as powerful tools in mitigating the challenges faced by individuals with dyslexia [4]. These technologies, which include a diverse array of devices, software, and systems, can greatly improve the abilities of individuals with dyslexia in multiple areas. For example, tools such as text-to-speech software, screen readers, and word prediction applications can enhance access to and understanding of written material. Speech-to-text software, grammar checkers, and writing tools can enhance both the quality and efficiency of written communication. Additionally, digital calendars, task management apps, and note-taking solutions can improve organization and time management skills. Educational software and applications provide tailored instruction and support, catering to the specific needs of individuals with dyslexia. By leveraging assistive technology, individuals with dyslexia can overcome obstacles, improve their academic performance, and achieve greater independence. [5].

IV. ADVANTAGES OF EXISTING TOOLS

Current assistive technologies provide substantial benefits for individuals with dyslexia. Below are the key advantages:



- Improved Reading Comprehension: Text-to-speech tools convert written text into spoken words, helping users overcome reading difficulties, enhancing comprehension, and reducing cognitive strain.
- Enhanced Writing Support: Speech-to-text software aids in writing by allowing users to focus on content creation without being hindered by spelling or grammatical challenges.
- Personalized Learning Experiences: AI-powered solutions, such as [6] the AI-based Augmentative Alternative Communication (AI-A2C) [7] model, adapt content to the learner's needs, providing real-time feedback and improving engagement.
- Boost in Academic Performance: The use of assistive technologies can lead to significant improvements in academic achievements, particularly when implemented early in the learning process
- Increased Self-Esteem and Independence: These tools foster confidence and independence by enabling learners to tackle tasks they previously found challenging.
- Educational System Limitations: Schools and institutions face budgetary constraints, lack proper infrastructure, and often fail to provide adequate training for teachers to implement these technologies effectively.
- Need for Policy Support: Addressing these barriers requires reducing costs, improving accessibility, and formulating supportive educational policies to ensure these technologies reach their full potential.

V. CHALLENGES AND BARRIERS

Despite the clear benefits, the widespread adoption of assistive technologies faces several challenges, which include:

- High Costs: Assistive technologies are often expensive, making them inaccessible to many students, particularly those in low-income regions or from disadvantaged backgrounds.
- Lack of Awareness Among Educators: Many educators are unaware of cognitive disabilities and the effective use of assistive technologies, limiting their integration into classrooms.
- Societal Stigma: Learning disabilities carry societal stigma, discouraging both students and families from using assistive tools, resulting in low acceptance rates.
- Educational System Limitations: Schools and institutions face budgetary constraints, lack proper infrastructure, and often fail to provide adequate training for teachers to implement these technologies effectively.
- Need for Policy Support: Addressing these barriers requires reducing costs, improving accessibility, and formulating supportive educational policies to ensure these technologies reach their full potential.

VI. KEY DEVELOPMENTS IN ASSISTIVE TECHNOLOGY

- AI-Driven Customization o Personalized learning experiences through adaptive AI [9][8], tailoring tools to individual needs. o Examples: Google's AI-based reading tutor and Learning Ally's human-narrated audiobooks.
- Augmented Reality (AR) and Wearables AR overlays to assist in real-world text interpretation. Wearable devices like smart glasses providing on-the-go reading support.
- Natural Language Processing (NLP) [10] o Advanced language models correcting grammar, enhancing sentence structure, and providing contextual suggestions. Example: Grammarly Premium's tone and clarity tools.
- Multisensory Learning Platforms Combining visual, auditory, and tactile stimuli to enhance learning. Examples: Touch screens with styluses for writing practice.
- Integration into Mainstream Tools Accessibility features embedded in platforms like Microsoft Office (Immersive Reader) and Google Workspace (Voice Typing, Read Aloud).
- Collaborative Learning Apps Tools like Voice Dream Reader and Book share, which provide synchronized reading and interactive interfaces

VII. IMPLEMENTATION IN EDUCATIONAL SETTINGS

A. Integration in Schools and Classrooms

Effective implementation of assistive technology (AT) requires thoughtful strategies and supportive environments:

1) Classroom-Level Strategies:

- Device Accessibility: Schools provide students with laptops, tablets, or Chromebooks pre-installed with assistive tools like Microsoft Immersive Reader, Google Read and Write, or Speechify.
- Software Deployment: Learning management systems (LMS) incorporate apps such as Learning Ally and Kurzweil for reading and writing support.
- Universal Design for Learning (UDL): Curriculum designed with built-in accessibility features, such as dyslexia-friendly fonts and text-to-speech functionality, benefits all students.



- Individualized Education Programs (IEPs): Tailored AT solutions aligned with students' specific needs and learning goals are incorporated into IEPs.
- 2) Whole-School Initiatives:
 - Technology Labs: Dedicated spaces equipped with devices and software for one-on-one or small group AT sessions.
 - Teacher Training Programs: Schools conduct professional development workshops to train educators in integrating at into lesson plans effectively.
 - Collaborative Learning: Schools encourage group projects using tools like Voice Dream Reader or collaborative apps, reducing stigma and enhancing peer support.
- 3) Policy Support:
 - Government Initiatives: Policies like the Individuals with Disabilities Education Act (IDEA) mandate access to AT for students with disabilities
 - Funding Opportunities: Grants and scholarships enable schools to procure and maintain AT resources.

B) Teacher and Student Perspectives

1. Teacher's Perspectives:

- Benefits: Promotes inclusivity, allowing every student to engage actively. Streamlines differentiation by providing resources designed for various learning speeds. Increases confidence in tackling challenges associated with dyslexia.
- Challenges: Professional Development: Educators may need continuous training to remain informed about the latest advancements in assistive technology. Alignment: It is essential to ensure that technology is effectively integrated with curriculum objectives. Resource Limitations: Schools with fewer resources may face challenges due to restricted funding or limited access to assistive technology tools.

2. Student Perspectives:

- Benefits: Assistive tools like text-to-speech apps promote increased independence by enabling students to complete tasks without constant support, while multisensory tools enhance engagement by making learning more interactive and enjoyable. Additionally, features that support spelling, reading, and writing help improve overall performance, allowing students to focus on comprehension and creativity.
- Challenges: While assistive technology (AT) tools offer significant benefits, they come with challenges such as stigma, as some students may feel singled out when using them in traditional classrooms. Additionally, adapting to new tools can feel overwhelming due to the learning curve involved, and access inequality remains a concern, as not all students have the same availability of AT tools outside school environments.

VIII. EMERGING TRENDS IN ASSISTIVE TECHNOLOGY

Emerging technologies are revolutionizing assistive care through innovations like AI-driven personalization, where machine learning models tailor devices to individual needs, such as speech recognition for accents or adaptive prosthetics learning movement patterns. Brain-Computer Interfaces (BCIs) enable direct device control via neural signals, offering transformative solutions like thought-controlled communication tools, robotic arms, or wheelchairs for individuals with severe motor impairments. Wearables and IoT integration further enhance accessibility, with smart devices like glasses seamlessly connecting to home automation systems. Augmented and Virtual Reality (AR/VR) create immersive experiences for therapy and skill development, such as virtual environments for social interaction training or rehabilitation. Robotics powered by AI contribute to personal care and companionship, particularly for the elderly or those with disabilities, while affordable, scalable solutions like 3D-printed devices and open-source software ensure global accessibility, especially in underprivileged areas.

IX. AREAS FOR ENHANCEMENT AND DEVELOPMENT

- Usability and Accessibility Focus on user-friendly interfaces to minimize the learning curve for users. Enhance accessibility through features like voice control, gesture recognition, and tactile feedback.
- Cross-Platform Interoperability Ensure seamless operation of devices across different ecosystems such as Windows, macOS, and Android. Example: Develop a unified app that synchronizes all assistive tools in real time.
- Battery and Energy Efficiency Develop long-lasting and quick-charging battery solutions. Explore renewable energy sources such as kinetic or solar charging for devices.
- Ethical and Privacy Concerns Address data security in assistive technologies to protect sensitive user information. Ensure transparency in AI decision-making processes, especially in critical systems.



- Community-Driven Innovation Crowdsourcing ideas from users and caregivers to identify real-world challenges. Create collaborative platforms for open innovation and continuous feedback.
- Regulatory and Policy Support Advocate for stronger government and organizational backing for assistive technology research and development. Ensure subsidies and insurance coverage for high-cost devices.
- Global Outreach and Inclusivity Design culturally sensitive and language-inclusive technologies. Expand accessibility standards across diverse socio-economic environments.

X. CONCLUSION

This article examines the transformative capabilities of AI driven assistive technologies (AT) in tackling the difficulties encountered by individuals with dyslexia. Innovations such as text-to-speech and speech-to-text have shown considerable advantages in enhancing reading comprehension, writing skills, and tailored learning experiences. However, obstacles such as high costs, insufficient teacher training, and societal prejudices impede broader implementation. Effective integration necessitates the implementation of classroom strategies such as Universal Design for Learning (UDL) and Individualized Education Programs (IEPs), complemented by comprehensive school initiatives that include technology labs, teacher training, and collaborative learning environments. Emerging trends like AI-driven personalization, brain-computer interfaces, wearable Internet of Things (IoT) devices, and augmented/virtual reality (AR/VR) have the potential to transform assistive technology (AT) by improving accessibility, customization, and engagement. Addressing factors such as usability, energy efficiency, ethical implications, and cultural inclusivity will be crucial for future developments. By navigating these challenges and fostering innovation, AI-enhanced AT can empower students with dyslexia, unlocking their potential and fostering inclusivity in the educational landscape.

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