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A review of Artificial Intelligence in Dyslexia: Current Constraints and the Road Ahead

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Abstract

Artificial intelligence (AI) is playing an increasingly significant role in enhancing the identification and support of individuals with dyslexia. This review outlines the current advancements while highlighting several limitations within the field. A key concern is the limited diversity in the datasets used to train AI models, which often originate from specific geographic and linguistic backgrounds. This lack of diversity challenges the applicability of AI solutions across global populations, where dyslexia may manifest differently. Moreover, many studies reviewed are limited by small sample sizes and experimental contexts, reducing their relevance to real-world applications.

Ethical considerations such as data privacy, transparency of algorithms, and fairness are also inadequately addressed in existing research. Additionally, while AI tools show promise in early detection and personalized interventions, they often fail to consider broader challenges faced by dyslexic learners, including emotional well-being and long-term academic success. Looking ahead, future research should focus on creating inclusive AI models through culturally diverse datasets and interdisciplinary collaboration. Emphasis must also be placed on developing transparent, interpretable, and ethically sound AI systems. Longitudinal studies are necessary to evaluate the sustained impact of AI-driven interventions beyond short-term improvements. Furthermore, ensuring equitable access to these technologies across socioeconomic groups remains critical.

By addressing these gaps and moving toward responsible implementation, AI holds the potential to significantly transform the educational and clinical landscape for individuals with dyslexia, offering more personalized and inclusive support strategies.

Introduction

Dyslexia is a neurodevelopmental disorder that impairs an individual's ability to read, write, and spell, despite having normal intelligence and receiving appropriate education. It is one of the most common learning disabilities, affecting approximately 5-10% of the population worldwide (Shaywitz & Shaywitz, 2005). The primary characteristic of dyslexia is difficulty with phonological processing, which is crucial for decoding and understanding written language. As a result, individuals with dyslexia face challenges in word recognition, spelling, and reading fluency, which can lead to academic struggles and emotional difficulties (Snowling, 2013).

The early identification and intervention for dyslexia are vital to minimize these challenges and to ensure that affected individuals can access education effectively.

Traditionally, the diagnosis of dyslexia relies on clinical assessments that involve reading tests, phonological awareness tasks, and observation of behavioral patterns (Shaywitz, 2003). While these assessments are effective, they are time-consuming and heavily dependent on the expertise of clinicians. Furthermore, early detection is often challenging, as the signs of dyslexia may not become evident until later stages of schooling. Early identification, however, is critical, as timely intervention has been shown to improve reading and academic outcomes for individuals with dyslexia (Fletcher et al., 2019).

In recent years, artificial intelligence (AI) has emerged as a promising tool for enhancing the diagnosis, intervention, and support for individuals with dyslexia. AI technologies, including machine learning (ML) and natural language processing (NLP), offer innovative ways to automate and improve various aspects of dyslexia research and management. One of the key areas where AI is being applied is in early detection. Machine learning algorithms can analyze patterns in large datasets, such as behavioral data, eye-tracking metrics, and neuroimaging scans, to identify signs of dyslexia in children before traditional diagnostic assessments are conducted. For instance, studies have demonstrated that AI models, such as convolutional neural networks (CNNs), can achieve high accuracy rates (above 90%) in detecting dyslexia using data from eye-tracking or fMRI scans (Alkhurayyif & Wahab Sait, 2024; Tamboer et al., 2016).

Beyond detection, AI is also making significant strides in the development of personalized learning interventions for dyslexic individuals. AI-powered educational tools can tailor learning content to meet the unique needs of each learner, offering adaptive learning systems that adjust in real-time based on the student's performance. These interventions include gamified learning applications, text-to-speech tools, and software that simplifies complex text, all of which enhance reading comprehension and literacy skills in dyslexic learners (Dybuster, n.d.; Dysolve, 2024). Furthermore, AI-based technologies can provide immediate feedback and track learning progress, enabling educators to offer more individualized support.

Despite the promising applications of AI in dyslexia, challenges remain. Ethical concerns, such as data privacy, algorithmic bias, and the accessibility of AI tools, need to be carefully addressed. Additionally, the scalability and cross-cultural applicability of AI systems remain important considerations as the field develops. This review aims to examine the current state of AI in the diagnosis and support of dyslexia, highlighting both the advancements made and the challenges that must be overcome.

Objectives

The primary objective of this review is to critically examine the role of artificial intelligence (AI) in the identification, assessment, and intervention of dyslexia. Specifically, this paper aims to:

- Map recent developments in AI applications related to dyslexia over the last decade.
- Identify and categorize AI techniques (e.g., machine learning, natural language processing, computer vision) used in dyslexia research and intervention tools.
- Evaluate the effectiveness and limitations of AI-based approaches in early screening, diagnosis, and personalized support for individuals with dyslexia.

- Highlight ethical, practical, and educational implications of using AI technologies in real-world settings such as schools, clinics, and home-based learning environments.
- Propose future directions for interdisciplinary research and implementation of AI systems in the context of neurodiverse learning needs.

Methodology

This review follows a structured and systematic approach to ensure comprehensive and unbiased coverage of relevant literature on AI applications in dyslexia. The methodology includes the following steps:

- **Search Strategy**
  A systematic search was conducted using electronic databases such as PubMed, Scopus, IEEE Xplore, SpringerLink, and Google Scholar. Search terms included combinations of keywords such as *"dyslexia," "artificial intelligence," "machine learning," "early detection," "screening," "natural language processing,"* and *"neurodiversity."*
- **Inclusion and Exclusion Criteria**
  - **Inclusion**: Peer-reviewed articles published between 2015 and 2025

    Studies that applied AI techniques to dyslexia detection, intervention, or support; English language publications

    Both qualitative and quantitative studies.
  - **Exclusion:** Articles not focused on dyslexia or AI, editorial opinions, and studies lacking methodological clarity.
- **Selection Process**

  After removing duplicates, the titles and abstracts were screened for relevance. Full texts of eligible studies were then reviewed to determine final inclusion. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram was used to document the study selection process.
- **Data Extraction and Synthesis**

  Data were extracted using a standardized table including information such as authors, publication year, study aim, AI method used, data type (e.g., EEG, eye-tracking, text), key findings, and limitations. A thematic analysis was conducted to categorize findings under key areas such as early detection, personalized learning, and assistive technologies.
- **Quality Assessment**

Each selected study was assessed for methodological rigor, relevance, and ethical considerations using criteria adapted from recognized appraisal tools such as the CASP (Critical Appraisal Skills Programme).

PRISMA charting of Data:

Literature Review Findings:

1. AI for Early Detection and Screening of Dyslexia

Early diagnosis of dyslexia is essential for timely intervention. Several studies have focused on utilizing AI models to identify dyslexia during early childhood, often prior to formal diagnosis. These models analyze behavioral indicators such as phonological awareness, response times during literacy tasks, and eye movement patterns.

Machine learning techniques, including Support Vector Machines (SVM), Decision Trees, and Convolutional Neural Networks (CNNs), have shown high effectiveness in this area. For example, Asvestopoulou et al. (2019) applied a linear SVM model to eye-tracking data and achieved a screening accuracy of 97%. Similarly, Alkhurayyif and Wahab Sait (2024) used a multimodal detection model that combined fMRI, EEG, and behavioral data with CNNs and dimensionality reduction techniques, achieving accuracy rates exceeding 98%. These technologies offer a promising avenue for early detection, particularly in school and community settings where traditional neuropsychological assessments may not be feasible. However, extensive validation across diverse linguistic and cultural contexts is needed to mitigate biases.

2. AI-Based Diagnostic Tools Using Neuroimaging and Biosignals

Another area of focus is the application of AI to neuroimaging and biosignal data. These methods aim to identify structural and functional brain differences in individuals with dyslexia by applying deep learning models to datasets from EEG, fMRI, and MRI scans.

For instance, Martinez-Murcia et al. (2023) used denoising autoencoders to analyze EEG connectivity patterns in dyslexic children, uncovering significant biomarkers associated with reading difficulties. Tamboer et al. (2016) examined structural MRI data using SVM algorithms and identified neuroanatomical differences that could predict dyslexia with an accuracy of 80%. These AI-driven diagnostic methods provide more objective, data-based insights compared to traditional diagnostic tools. However, their high costs and technical requirements often limit their availability outside of research settings.

3. AI-Powered Intervention and Learning Support Tools

In addition to detection and diagnosis, AI has been employed to develop adaptive learning environments for dyslexic individuals. Intelligent tutoring systems, real-time feedback mechanisms, and gamified educational apps are examples of tools designed to personalize learning experiences.

For example, Dysolve is a recent AI-powered application that offers gamified reading and spelling exercises tailored to an individual's performance data. Similarly, platforms such as Dybuster use AI to support multisensory learning, dynamically adjusting task difficulty based on learner needs. These tools have shown considerable promise in improving motivation and learning outcomes. However, further research is needed to evaluate their long-term effectiveness and scalability across various educational environments.

4. Natural Language Processing (NLP) and Reading Assistance Technologies

Natural Language Processing (NLP) plays a crucial role in supporting reading comprehension for individuals with dyslexia. AI-powered tools can simplify complex texts, restructure sentences, and provide phonetic cues or audio support.

One example is the LARF (Let AI Read First) system, which uses large language models (LLMs) to annotate and simplify digital texts in real time, aiding dyslexic users in better understanding content. Text-to-speech technologies powered by AI have also significantly improved in fluency and accuracy, enhancing accessibility to reading materials. Despite their advantages, challenges remain in ensuring readability without oversimplification, as well as addressing ethical concerns related to data privacy and dependency on AI systems.

5. Ethical and Practical Considerations in AI for Dyslexia

As AI becomes more integrated into tools for dyslexia, various ethical and practical issues must be considered. These include concerns about data privacy, algorithmic bias, over-reliance on automated systems, and the digital divide that may limit access to AI-powered interventions.

Research suggests that AI tools should complement, not replace, human expertise. Ensuring that these tools are inclusive, transparent, and regularly validated across diverse populations is essential for achieving equitable outcomes.

Table 2: Summary of Literature Review Findings on AI and Dyslexia

Theme	Study	Key Findings	AI Methods Used
1. AI for Early Detection and Screening	Asvestopoulou et al., 2019	High accuracy (97%) in detecting dyslexia using eye-tracking data and machine learning models	Support Vector Machines (SVM), Eye-tracking

	Alkhurayyif & Wahab Sait, 2024	Multi-modal AI model combining fMRI, EEG, and behavioral data for early dyslexia detection (98% accuracy)	CNN, Dimensionality Reduction, fMRI, EEG
	Karabekiroglu et al., 2021	Early detection of dyslexia in children using machine learning models based on phonological processing tasks	Random Forest, Phonological Processing
	Tassis et al., 2018	Utilized machine learning to predict dyslexia risk in children based on classroom activities and behavioural data	Decision Trees, Classifier Models
2. AI-Based Diagnostic Tools Using Neuroimaging and Biosignals	Martinez-Murcia et al., 2023	Identified dyslexia biomarkers from EEG data using denoising autoencoders for better classification of dyslexic patterns	Denoising Autoencoders, EEG
	Tamboer et al., 2016	Identified structural brain differences in dyslexic individuals using MRI and machine learning	SVM, MRI
	Li et al., 2017	AI models analysing fMRI data to identify neurobiological signatures of dyslexia	CNN, fMRI
	He et al., 2020	Use of machine learning on EEG patterns to predict dyslexia risk in children, with high sensitivity and specificity	SVM, EEG
3. AI-Powered Intervention and Learning Support Tools	Dybuster (No date)	AI-driven multisensory learning software to reinforce reading skills, adaptable to individual needs	Multisensory AI Learning, Adaptive Feedback
	Dysolve, 2024	AI-based gamified learning tool to improve reading and spelling for dyslexic learners, personalized feedback	Gamified AI Learning, Real-time Adaptation
	Sweeney et al., 2019	Use of AI to provide personalized learning interventions for dyslexic	Reinforcement Learning,

		children through interactive platforms	Adaptive Learning Systems
	Chien et al., 2022	AI-based mobile app for personalized dyslexia intervention, improving reading fluency and engagement	Mobile AI Learning, Adaptive Feedback Systems
4. NLP and Reading Assistance Technologies	LARF (Let AI Read First), 2024	Simplified and annotated text using LLMs, real-time support for reading comprehension in dyslexic individuals	Large Language Models (LLMs), Text Simplification
	Various text-to-speech tools (No date)	AI-driven text-to-speech technology for improving reading fluency and accessibility for dyslexic users	AI Text-to-Speech, NLP
	MacDonald et al., 2020	Integration of NLP tools to assist dyslexic readers by providing real-time feedback on spelling, sentence structures, and text complexity	NLP, Feedback Systems
	Verma et al., 2023	AI-powered summarization and annotation tools aimed at simplifying complex educational content for dyslexic learners	Text Summarization, NLP
5. Ethical and Practical Considerations in AI for Dyslexia	Various sources (general discussion)	Ethical concerns regarding data privacy, algorithmic transparency, and over-reliance on AI, advocating for human oversight	-
	Sharma et al., 2022	Raised concerns about algorithmic biases and access to AI-powered dyslexia tools for underserved communities	-
	Greene et al., 2021	Discussed the role of AI in personalized education and the potential for AI to reinforce inequities if not used thoughtfully	-

Discussion

The integration of AI in dyslexia research and intervention marks a significant shift toward personalized and data-driven education. The studies reviewed highlight AI's potential in enhancing early detection, streamlining

diagnosis, and providing adaptive learning support. The use of various AI techniques, such as SVMs, CNNs, LLMs, and denoising autoencoders, underscores the breadth of innovation in this field.

Notably, AI's ability to detect dyslexia early—using non-invasive methods like eye-tracking and behavioural analysis—holds promise for transforming school-based screenings and improving access to early intervention. Furthermore, AI applications utilizing EEG and MRI data for diagnostics provide robust, supplementary tools to traditional assessments.

AI-powered educational tools are also showing transformative potential by adapting to the individual needs and pace of dyslexic learners, which enhances academic progress, confidence, and engagement. However, many of these systems are still in the experimental phase and often lack cross-cultural validation. The small or homogenous samples used in most studies raise concerns about the generalizability of these tools across diverse populations.

Ethical concerns regarding AI's role in education must be addressed. Issues such as data privacy, transparency in algorithmic decision-making, and accountability are especially critical when dealing with neurodiverse groups. It is important that educators and clinicians receive adequate training in the responsible and effective integration of AI technologies.

Limitations

While this review provides an extensive overview of the current use of artificial intelligence (AI) in dyslexia, there are several limitations to consider. First, the majority of studies reviewed were conducted in specific geographic regions, and most models are based on datasets from relatively homogeneous populations. This limitation raises concerns about the generalizability of AI tools across different cultural, linguistic, and socioeconomic groups. Dyslexia present differently in various languages and cultures, and a model trained on English language data may not perform as effectively in regions where dyslexia manifests with different characteristics.

Additionally, although AI models have shown great promise in detecting dyslexia early and creating personalized interventions, many of the reviewed studies are based on experimental setups and small sample sizes. This restricts the ability to draw definitive conclusions regarding the effectiveness of these technologies in real-world settings. The deployment of AI in clinical and educational environments requires further validation to ensure its reliability and scalability. Moreover, ethical considerations, including concerns about privacy, algorithmic bias, and the transparency of AI decision-making, remain largely underexplored in some of the studies reviewed. More robust guidelines are needed to safeguard the users of these technologies.

Finally, many of the AI tools discussed focus primarily on early detection and personalized learning interventions but do not address the broader educational and social challenges faced by dyslexic learners. While AI-based interventions can support reading skills, they do not always account for the wider impacts of dyslexia, such as emotional well-being, self-esteem, and long-term academic success.

Future Directions

As AI continues to evolve, several future directions could enhance the understanding and support for individuals with dyslexia. A major area for future research is the expansion of AI models to include diverse populations. Cross-cultural and multilingual studies should be prioritized to ensure that AI tools can be adapted to different

linguistic and cultural contexts. Larger and more diverse datasets would help improve the accuracy and generalizability of these tools across varied populations.

Moreover, integrating AI into multidisciplinary frameworks could provide a more holistic approach to supporting dyslexic learners. Collaboration between AI researchers, psychologists, educators, and clinicians could result in AI systems that not only detect dyslexia but also provide personalized educational and psychological support. Future developments could also focus on improving the transparency of AI models, ensuring that these systems are interpretable and accountable, particularly when making decisions that impact vulnerable populations.

Another area for growth is the longitudinal study of AI-based interventions. While many AI tools have demonstrated effectiveness in controlled environments, there is limited data on their long-term impact on dyslexic individuals' academic outcomes and emotional well-being. Future studies should include larger, more representative samples and assess the long-term effects of AI-driven interventions in both clinical and real-world educational settings.

Finally, ethical issues must be addressed in future developments. The integration of AI into dyslexia diagnosis and intervention must prioritize user privacy, algorithmic fairness, and accessibility. AI tools should be developed with clear ethical guidelines to ensure that they are used responsibly and equitably, offering equal access to all learners, irrespective of their socioeconomic background or geographic location. By addressing these limitations and pursuing the future directions outlined above, AI has the potential to significantly enhance both the understanding and support of individuals with dyslexia, ultimately transforming educational and clinical practices for dyslexic learners worldwide.

Conclusion

AI has emerged as a powerful tool in advancing the understanding and support of individuals with dyslexia. From early detection and diagnostic tools to personalized learning environments and reading assistants, AI is revolutionizing how educational and clinical services address learning difficulties. However, the full potential of these tools will only be realized through collaborative, interdisciplinary efforts that prioritize ethical implementation, inclusivity, and continuous evaluation.

Future research should focus on enhancing the scalability and cultural adaptability of AI models, improving transparency in algorithmic decisions, and ensuring that AI tools complement—not replace—human expertise within educational systems.

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