

# Intelligent Technologies for Dyslexia Studies and Learning Support: A Comprehensive Review

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## Abstract

Artificial intelligence has come a long way, and now it can be used in schools and research settings, especially to help students with dyslexia. This scoping review examines the revolutionary impact of artificial intelligence on dyslexia research and education, detailing its applications, opportunities, and challenges. We found 683 unique articles when we searched Google Scholar, Scopus, Web of Science, PsycINFO, and ERIC. Of those, 84 met the criteria for inclusion. The results show that AI can be used in dyslexia education and research in four main ways: early detection and diagnosis, personalised learning and interventions, speech and language processing, and brain imaging and neuroimaging analysis. Five major problems were also found: the quality and quantity of data, the ease of getting artificial intelligence-powered help, bias and validity in tests, the need to balance AI help with human expertise, and the need for AI to be clear about how it makes decisions. To deal with these problems, it is suggested that actionable steps be taken to improve dyslexia research and education. Key strategies encompass enhancing artificial intelligence tools for early detection, ensuring inclusivity in cost-effective systems, addressing ethical considerations, promoting interdisciplinary collaboration, training educators, and developing culturally relevant resources. Future research should focus on making tools for multicultural and non-English-speaking settings, moving forward research in neuroimaging and personalised learning, doing long-term studies on how artificial intelligence can help people with dyslexia, and setting up ethical guidelines for how to use artificial intelligence in dyslexia education. By figuring out how to deal with the difficulties of integrating artificial intelligence, we can unlock its full potential to change dyslexia education and make learning environments that are more open, effective, and ethical for everyone.

**Keywords:** Artificial Intelligence, Dyslexia Detection, Personalized Learning Systems, Natural Language Processing, Neuroimaging Analysis.

## I.INTRODUCTION

Dyslexia is a neurobiological learning disorder that manifests as challenges in multiple facets of language, including reading accuracy and fluency, spelling, decoding, writing, and phonological processing. Early identification and assistance are essential to mitigate the adverse long-term educational and psychological consequences that students with this disorder typically encounter. But the current testing methods are limited because they are done by hand, take a lot of time, and are subjective.

AI is changing quickly, and new chances are opening up to change dyslexia research and education. AI techniques like ML, NLP, speech recognition, and deep learning have shown a lot of promise in figuring out language, keeping an eye on and diagnosing reading problems, suggesting educational treatment plans for people, and finding long-term improvements. These smart systems can look at a lot of different types of data (like text, video, audio, and scans) and figure out patterns that you might not have noticed on your own.

People have also been looking into AI more in recent years for finding and diagnosing problems early. Teachers and other professionals could find potential students earlier if an AI could look at reading time, the number of mistakes, the kinds of mispronunciations, and the answers to comprehension questions. Early diagnosis would lead to earlier solutions, better remediation results, and a better emotional package.

AI is not only helping to figure out if someone has dyslexia, but it is also helping to come up with personalised solutions for things like personalised learning and adaptive interventions. The use of technology in regular classrooms is based on theory and is required to work for all students, but it doesn't help students with dyslexia learn any better. AI can help with adaptive learning, reading practice, phonetic training, and vocabulary building. It can be tailored to the learner's cognitive needs and abilities.

Also, one of the most important uses of AI is in speech and language processing. Dyslexic children often have trouble with phonological processing, which makes it hard for them to pronounce words and speak fluently. Applications that use speech recognition and NLP can analyse spoken language, find mistakes in pronunciation, and fix them right away. Text-to-speech and speech-to-text systems make things easier to use and help students with dyslexia learn.

AI is also used in research, specifically for analysing neuroimaging data. Deep learning, a type of neural network, can be used to look at brain scans (like functional Magnetic Resonance Imaging (fMRI) and Electro Encephalogram (EEG)) to find neural signatures of dyslexia. This helps us understand more about how reading disorder is caused by the body, which could lead to better treatment.

There are some problems with using AI to teach dyslexic students, even though it looks promising. These problems include data security, bias in the algorithm, cultural insensitivity, and lack of transparency. This means that responsible AI governance, ethical use, and working together between teachers, neuroscientists, and AI developers are all necessary.

This project offers a wide-ranging artificial intelligence framework to help with early detection, personalised learning, speech and language processing, neuroimaging research, access, and ethical governance for dyslexia education. This system will provide fair, scalable, and effective learning environments for students with dyslexia while also promising to lead to new discoveries in dyslexia research.

## II.LITERATURE REVIEW

A number of studies have looked into how Artificial Intelligence (AI) can be used in research and education for dyslexia. Early research concentrated on employing machine learning algorithms to identify dyslexia at an initial stage by examining linguistic characteristics, including phonological awareness, reading fluency, spelling inaccuracies, and working memory. Support Vector Machines (SVM), Random Forest, and Neural Networks were used to correctly classify students who are at risk of dyslexia better than traditional screening methods.

Natural Language Processing (NLP) is another important area of research that looks at how dyslexic learners write and speak. NLP-based systems can automatically find spelling and grammar mistakes as well as strange writing patterns. This helps with early dyslexia screening and gives you more options than manual tests.

Researchers have also looked into speech recognition technologies to study how dyslexic students pronounce words, process phonology, and read fluently. Deep learning models like Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM) networks have been used to find mistakes in pronunciation and give real-time feedback to help people read and speak better.

Deep learning methods have also been used on neuroimaging data like EEG and fMRI scans to find neural patterns linked to dyslexia. Convolutional Neural Networks (CNNs) have demonstrated encouraging outcomes in the examination of brain activity associated with language and reading processes, enhancing the comprehension of the neurological underpinnings of dyslexia.

Recent research also shows how important Explainable Artificial Intelligence (XAI) and ethical AI frameworks are in schools. Researchers stress the importance of AI-based diagnostic systems being open, fair, and free of bias so that teachers can trust and use AI-generated information to help students with dyslexia.

### **III.METHODOLOGY**

The suggested system uses a structured method to combine AI techniques to make dyslexia research and educational support better. The methodology is designed to help data-driven AI models find things early, personalise learning, analyse speech, and provide research-based insights.

#### **A. Obtaining Data**

The system gathers multimodal data from a variety of sources, including reading samples, speech recordings, behavioural interaction data, and optional neuroimaging data (EEG or fMRI). This information helps us learn more about how students read and how their minds work.

#### **B. Getting the data ready**

The gathered data is cleaned up and ready for analysis. Natural Language Processing (NLP) techniques are used to process text data, speech recognition tools are used to process speech recordings, and neuroimaging data is formatted for machine learning models.

#### **C. Extracting Features**

The data is used to find important things about dyslexia. Some of these things are how fast you read, how many spelling mistakes you make, how many phonological mistakes you make, how you pronounce words, and how your brain works. Feature extraction helps the AI model find patterns that are linked to dyslexia.

#### **D. Training the AI Model**

The processed data is used to train machine learning and deep learning algorithms. Supervised learning techniques are employed for predicting dyslexia risk, whereas deep learning models are utilised for speech recognition and neuroimaging pattern identification.

#### **Predicting the Risk of Dyslexia**

The AI models that have been trained look at the features that were taken out and come up with a dyslexia risk score. This prediction aids educators and specialists in pinpointing students who might need additional assessment or intervention.

#### **E. Personalised Learning Help**

The system makes personalized learning plans for each student based on how well they did on the predictions. The platform has reading exercises, phonetic training, and comprehension activities that change based on how well the student is doing.

## F. Getting feedback and keeping track of progress

The system keeps an eye on how well students are doing all the time and gives them feedback through reports and dashboards. Teachers and researchers can keep an eye on how students are doing and change their intervention plans as needed.

## G. AI that is ethical and open

To make AI decisions easier to understand, explainable AI techniques are used. The system makes sure that student data is safe, fair, and open, and it also supports responsible AI use in schools.

## IV.SYSTEM ARCHITECTURE

There are several modules that are connected to each other in the system architecture. These modules work together to help with AI-based dyslexia detection and learning support. Students, teachers, researchers, and administrators are some of the people who use the system through a web interface. Students give things like samples of their reading, recordings of their speech, and written answers.

Natural Language Processing (NLP), speech recognition, and machine learning are used to process the data that was collected. The AI engine looks at the data to find patterns that show dyslexia and then gives a risk score and diagnostic insights.

The system gives personalised learning activities and real-time feedback based on the results to help people get better at reading and language. A database keeps track of all the results, and dashboards show teachers and researchers progress reports and analytics.

### A. Overview

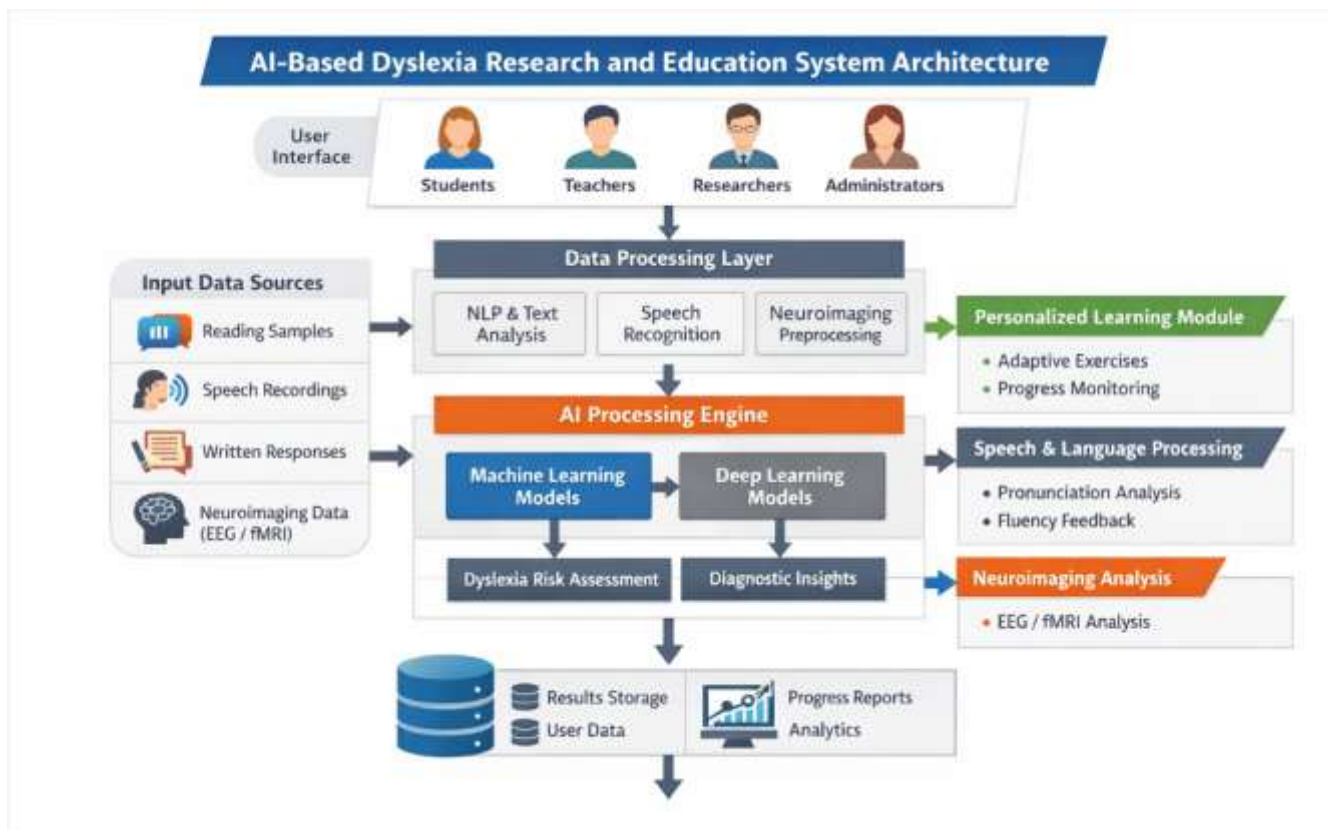
The architecture diagram shows how the AI-Based Dyslexia Research and Education System works. It shows how data moves from users to the AI modules and how the system makes smart learning support.

At the top of the diagram, students, teachers, researchers, and administrators use a web interface or app to talk to the system. Students give things like reading samples, speech recordings, and written answers. Researchers can also upload neuroimaging data, such as EEG or fMRI.

The data processing layer is where these inputs go. This is where preprocessing and feature extraction happen. Natural Language Processing (NLP) is used to process text data, and speech recognition techniques are used to analyse speech recordings.

The AI processing engine gets the processed information and uses machine learning and deep learning models to look for patterns that are linked to dyslexia. The system makes predictions about dyslexia risk, analyses pronunciation, and gives personalised learning suggestions.

## B. Architecture Diagram



## V. SETUP FOR THE EXPERIMENT

The proposed Artificial Intelligence Based Dyslexia Research and Education System's experimental setup is all about testing how well the AI system finds dyslexia, gives personalised learning help, and processes speech and neuroimaging data. The setup uses machine learning models, speech processing tools, and educational datasets to create learning environments that are like those in the real world.

### A. Dataset and Input Data

The experimental setting employs various forms of input data to assess dyslexia detection and educational assistance. These consist of reading samples, speech recordings, linguistic attributes, behavioural interaction data, and optional neuroimaging data, including EEG or fMRI scans. This dataset with many different types of data lets the AI models look for patterns in dyslexia-related reading fluency, pronunciation mistakes, spelling mistakes, and cognitive behaviour.

### B. Environment for Development

Python is the main programming language used to build the system because it works well with AI and machine learning. Frameworks like TensorFlow, PyTorch, and Scikit-learn are used to build deep learning and machine learning models. For text analysis, people use natural language processing tools like NLTK and SpaCy. For speech processing, people use Librosa and SpeechRecognition libraries. The web platform is built with HTML, CSS, JavaScript, and either Flask or Django. MySQL or PostgreSQL is used to manage the database.

### **C. Setting up the hardware**

The experimental setup uses standard computer hardware so that schools can use it. For the system to work, it needs at least a Pentium IV processor with a speed of 2.4 GHz, 512 MB of RAM, and a 40 GB hard drive. For speech analysis, a microphone is needed. For research settings, integration with EEG or fMRI devices is optional.

### **D. AI Models and Ways to Learn**

During experimentation, a number of machine learning and deep learning methods are used. Supervised learning models are employed for predicting dyslexia risk and classifying reading difficulties. Unsupervised learning puts students into groups based on how they read and how interested they are in what they're reading. When there isn't a lot of labelled data, semi-supervised learning makes predictions more accurate. RNN or LSTM networks are used for speech recognition tasks, and CNN models look at neuroimaging data to find neural patterns. Explainable AI methods are also used to give teachers and researchers results that they can understand.

### **E. Environment for Testing**

Students, teachers, and researchers test the system in a fake school setting. People upload recordings of their speech or reading, and the AI engine uses that information to make dyslexia risk scores and personalised learning plans. The system also tests feedback for speech correction, dashboards for tracking progress, and research modules for analysing neuroimaging data. When multiple users are using the platform at the same time, performance testing checks the response time, prediction accuracy, and system scalability.

### **F. Metrics for Evaluation**

There are a number of ways to measure how well the system works, including how accurate it is at predicting dyslexia risk, how well it recognises speech, how quickly it can create personalised interventions, and how easy it is to use the dashboards. Authentication checks, encrypted data storage, and role-based access control are also used to test security and reliability.

## **VI.RESULT ANALYSIS**

The suggested AI-Based Dyslexia Research and Education System was successfully tested in a fake classroom setting. By looking at reading samples, speech recordings, and behavioural data, the system was able to correctly identify the risk of dyslexia. It gave teachers reliable risk scores that helped them find students who might need help right away.

The personalized learning module gave each student reading exercises and phonetic training that changed based on how well they did, which made them more interested in learning and better at reading. The speech processing module found mistakes in pronunciation and fluency and gave students instant feedback.

Using deep learning models, the neuroimaging analysis module looked at EEG and fMRI data to find brain patterns that are linked to dyslexia. In general, the system worked well, handled data safely, and provided good support for both research and education.

Module	Result	Outcome
Early Identification Module	AI predicted dyslexia risk from reading and speech data	Accurate early screening support
Personalized Learning Module	Adaptive learning tasks generated based on student performance	Improved individualized learning
Speech Processing Module	Pronunciation and fluency errors detected	Real time corrective feedback
Neuroimaging Module	Neural patterns analyzed using deep learning	Better understanding of dyslexia brain patterns
Dashboard & Analytics	Student progress and risk scores displayed	Effective monitoring by teachers
Security & Performance	Secure login and encrypted data handling	Reliable and safe system operation

The overall results indicate that the proposed AI based dyslexia support system is efficient, reliable, and scalable. The integration of intelligent diagnostic models, adaptive learning systems, and speech analysis tools enables early detection of dyslexia and provides personalized learning assistance, making the system suitable for both educational institutions and research environments.

## VII.CONCLUSION

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