Mobile and Simulation-based Approach to Reduce Dyslexia in Children

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***Abstract* - A neurological learning impairment, dyslexia impair writing, phonemic awareness, reading fluency, and memory processing, making it challenging for people to understand and remember text. Conventional teaching approaches frequently lack flexibility and customization, which results in poor learning outcomes for dyslexic pupils. An AI-powered adaptive learning framework that combines three essential elements visual processing, short-term memory enhancement, and reading enhancement utilizing natural language processing is proposed in this study to solve these issues. The suggested system uses computer vision, machine learning, and natural language processing (NLP) techniques to provide adjustable difficulty levels, tailored learning routes, and real-time feedback. For phoneme-grapheme mapping, pattern recognition, and sequential recall tasks, deep learning models such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks are used. Technology reinforces reading comprehension and cognitive memory by dynamically adjusting according to individual performance. In accordance with experimental data, there has been a notable improvement in pattern recognition (97.2% accuracy), memory retention (40%), and reading fluency (30%). AI-assisted therapies improve dyslexic students' general reading and cognitive skills by offering tailored, gamified, and captivating learning experiences. By proving AI's efficacy in focused literacy treatments and filling in gaps in conventional dyslexia teaching, this study advances assistive educational technology.**

Keywords – Adaptive Learning, AI in Education, comprehension, dyslexia, Machine Learning, NLP, Reading Enhancement, shortterm_memory, simulation, Visual_processing.

I. Introduction

A. Problem Statement

Dyslexia is a neurodevelopmental disorder that impairs reading, writing, visual processing, and memory retention. Children with dyslexia face significant challenges in traditional learning environments owing to issues with visual processing, phonemic awareness, and short-term memory. Existing intervention options, such as one-on-one tutoring, phonics-based instruction, and assisted reading software, usually fail to create a customized, adaptable, and engaging learning environment [1], [2].

Studies have indicated that multisensory learning strategies, artificial intelligence (AI), and simulation-based activities improve dyslexic children's capacity to absorb visual information, process language, and maintain memory. However, current digital learning systems usually lack adaptive feedback mechanisms, real-time voice recognition, and AI-powered gamification, which would enhance learning effectiveness and interactivity [3], [4].

To bridge this gap, this study suggests developing a mobile and simulation-based application that integrates Machine Learning (ML), Natural Language Processing (NLP), and Computer Vision to help dyslexic youngsters. The technology is designed to enhance visual processing, reading comprehension, and memory retention through personalized and interactive exercises [5]. The suggested method will be assessed in terms of increased reading ability, memory retention rates, and user engagement [6].

B. Background

Dyslexia affect around 15-20% of the worldwide population, causing difficulties with phonemic awareness, word decoding, short-term memory recall, and reading comprehension. Conventional procedures need specialized supervision, which restricts accessibility. Advances in AI and NLP enable scalable systems that adapt to individual learning patterns. This study combines many AI-driven tactics to improve cognitive processing and reading abilities in dyslexic youngsters [7], [8], [9], [10]. This paper consolidates three independent studies: 1 - Visual interpreting Difficulties - Problems identifying letters, distinguishing similar-looking words, and interpreting spatial data. Enhancing shape recognition and pattern prediction using deep learning. 2 - Reading and writing difficulties - Include problems with phonemic awareness, spelling, and sentence structure. Leveraging Natural Language Processing and Machine Learning models to provide fluency assessment, real-time pronunciation correction, and phonemic awareness training. 3 - Short-term memory limitations - Include difficulty keeping and recalling knowledge, which reduces learning efficiency. Improving cognitive retention, memory recall, and adaptive learning through personalized AI-assisted exercises.

The proposed approach uses AI and ML-based adaptive learning modules to help dyslexic youngsters enhance their visual processing, comprehension, writing, and memory abilities [11] .

C. Significance

Dyslexia affect around 15-20% of the global population, making it one of the most frequent learning disabilities. Children with dyslexia have difficulties with reading, writing, visual processing, and short-term memory recall, which can have a significant impact on their academic progress and self-esteem. Traditional teaching techniques, such as phonics-based instruction and repetitious reading exercises, usually fail to satisfy dyslexic children's individual learning needs.

As a result, there is an urgent need for adaptive, technology-driven therapies that offer personalized and engaging learning experiences. This project attempts to create a scalable, individualized solution for dyslexic children by combining AI-based adaptive learning, real-time speech recognition, and gamified interactive activities. This study is significant because it has the ability to improve dyslexic children's literacy and cognitive abilities while also providing instructors with an organized strategy to better understand their students' issues [12], [13], [14].

D. Objectives

The aim of this research is to build and develop a mobile application that uses machine learning and simulation approaches to help dyslexic children improve their reading, writing, visual processing, and memory abilities. The main goals are Develop a Visual Processing Module to improve letter and shape recognition, Design a Reading and Writing Enhancement Module that uses phonics-based learning and AI-powered speech-to-text tools, Implement a Short-term Memory Training Module using pattern recognition and recall exercises, Integrate Natural Language Processing (NLP) and Gamification to enhance user engagement, Evaluate the effectiveness of the application through prototype testing with dyslexic learners.

E. Hypotheses or Research Questions

The study will investigate the following research questions: 1 - How effective is AI-driven adaptive learning in improving the reading comprehension and fluency of dyslexic children? 2 - Can real-time NLP-based speech recognition provide immediate corrective feedback that enhances phonemic awareness? 3 - How does an AI-powered short-term memory training module impact cognitive retention and recall speed in dyslexic learners? 4 - Does an interactive, gamified approach to learning improve engagement and learning outcomes compared to traditional teaching methods?

II. LITERATURE REVIEW

Numerous studies have shown how effective AI-powered teaching resources are for dyslexia treatments, emphasizing developments in gamification, machine learning, and natural language processing (NLP). Since it is more successful than traditional language therapy, NLP-based voice analysis has been used extensively for phoneme detection, real-time pronunciation correction, and fluency evaluation. Similar to this, ML-driven language assessments improve reading fluency, comprehension, and word identification by offering adaptive difficulty modifications depending on user performance in real time, enabling a more individualized intervention [15], [16].

Despite these developments, the majority of dyslexia remediation strategies still concentrate on specific areas, such phonemic awareness or reading fluency, rather than using an integrated strategy that concurrently treats memory retention, visual processing, and reading abilities. According to studies, gamification strategies greatly improve dyslexic learners' motivation, engagement, and cognitive retention. Compared to traditional teaching methods, dyslexic students may fix mistakes more quickly thanks to AI-powered real-time feedback systems that further enhance pronunciation accuracy, word recognition, and comprehension abilities [17], [18].

Furthermore, sophisticated AI models such as Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks have been used in cognitive reinforcement and memory training. These networks dynamically modify training tasks according to individual learning styles. According to research, children with dyslexia benefit from multimodal learning strategies that integrate visual, aural, and interactive feedback mechanisms to increase their reading fluency, memory recall, and understanding. Additionally, shape and pattern recognition based on computer vision has demonstrated potential in improving visual processing, helping dyslexic learners more successfully discern letters, words, and sequences. It has also been demonstrated that AI-driven reading comprehension tools that use voice recognition, text-to-speech (TTS) synthesis, and gamified narrative improve literacy results and reading motivation . These results highlight how adaptive learning systems driven by AI may be used to provide comprehensive, successful dyslexia education programs. [19], [20].

III. METHODOLOGY

This research builds an AI-driven adaptive learning system for dyslexic children that combines Visual Processing, Short-Term Memory Enhancement, and Reading Enhancement with NLP to provide a tailored learning experience. The system uses CNNs for form identification, LSTM networks for memory training, and NLP models for real-time pronunciation correction. A Flutter-based mobile application has an interactive UI, while a Node.js and Flask backend handles AI-generated feedback. The MongoDB database holds user performance data, which enables dynamic difficulty modifications based on progress. This process guarantees that learning is personalized to individual requirements, strengthening weak areas while increasing interest. The next subsections go over the system's components, implementation methodology, and adaptive learning techniques [21].

A. Data Collection

The dataset used in this study was gathered through expert consultations and real-world insights P. Gowritharan, a speech and language therapist and counselor at Teaching Hospital in Jaffna, for this study through professional consultations and practical knowledge. Along with insights into current intervention strategies, namely the games and activities used in treatment sessions to support memory recall, phonemic awareness, and reading fluency, the data provides in-depth assessments of the cognitive and linguistic difficulties faced by dyslexic youngsters.

The information gathered includes:
1 - Case studies include behavioral patterns of children with dyslexia that highlight problems with visual processing, memory retention, and reading. 2 - Currently, dyslexia intervention programs include cognitive reinforcement games and therapeutic activities. 3 - Speech and language patterns, such as issues with phoneme identification, word decoding, and pronunciation. 4 - Game-based learning techniques that enhance short-term memory and phonemic awareness include

shape recognition puzzles, story-based reading, and auditory memory training exercises.

The development of customized ML-powered learning modules that mimic the efficacy of in-person dyslexia therapies in a digital, adaptive learning environment was made possible by this dataset. Insights from Teaching Hospital, Jaffna, were essential in confirming the efficacy of the ML model and guaranteeing that the suggested method is in line with realistic treatment strategies.
The following Figure 1(from https://dyslexialibrary.org/) and Figure 2 (from https://dyslexialibrary.org/) are used to gain knowledge on identifying dyslexia children.

Figure 1 Interactive Infomap

Figure 2 Interactive Infomap

B. System Design

The system is structured into three core components:

1. Visual processing module: Utilizes Convolutional Neural Networks (CNNs) for recognizing shapes, letters, and patterns to assist with visual discrimination. Implements Long Short-Term Memory (LSTM) networks for predicting patterns and adaptive difficulty adjustments. Features real-time tracking to refine user performance based on recognition accuracy.
2. Reading Enhancement using NLP: Employs speech recognition for real-time pronunciation analysis and fluency training. Provides corrective feedback based on word phonetics and sentence structuring. Uses AI-driven fluency assessments to track learning progress and adjust content difficulty accordingly.
3. Short term memory enhancement: Develops phoneme-grapheme mapping exercises to improve auditory and visual memory retention. Implements sequential recall tasks reinforced with NLP-based voice assistance. Uses deep learning for pattern recognition and reinforcement-based learning exercises. Adapts difficulty levels based on user progress, ensuring continuous cognitive improvement.

C. Implementation Framework

The implementation framework includes a Flutter-based mobile application with an interactive user interface, a Node.js backend with a Flask-based API for AI processing, and a MongoDB database for storing user progress and performance information. The system combines CNNs for image identification, LSTM networks for memory training, and natural language processing models for real-time pronunciation correction. AI-powered learning modules alter difficulty levels dynamically based on user feedback, ensuring tailored interventions. The backend connects with the AI models to deliver adaptive feedback, which increases engagement and retention. This framework offers a scalable, cloud-based architecture capable of providing real-time learning experiences to dyslexic youngsters [21].

1. Frontend - A Flutter-based mobile application designed for interactive learning and adaptive exercises [22].
2. Backend - Node.js integrated with a Flask-based API for AI model processing and data management [23].
3. Database - MongoDB stores user profiles, learning progress, and performance analytics [24].
4. Models - CNNs for visual recognition and object differentiation, LSTM networks for memory retention and cognitive adaptation, NLP for analyzing pronunciation and phonemic structure, Random Forest classifiers for optimizing personalized learning recommendations [25].

D. Adaptive learning approaches

The approach starts with a baseline cognitive evaluation that measures recall efficiency and response speeds. Based on the findings, the AI model dynamically modifies task complexity and reinforcement frequency. If a youngster struggles with certain activities, the system presents other learning approaches, such as auditory and visual reinforcements, to promote cognitive engagement.

IV. RESULTS AND DISCUSSION

The based on artificial intelligence adaptive learning system significantly improved dyslexic children's reading fluency, visual processing, and short-term memory recall. The experimental results revealed a 32% increase in phoneme recall accuracy, a 40% improvement in sequential retention rates, and a 28% decrease in reaction time for cognitive switching tasks. The CNN-based visual processing module obtained 97.2% accuracy, while the LSTM-based pattern prediction achieved 89.4% accuracy, therefore improving letter and shape identification. AI-driven adaptive difficulty modifications enhanced engagement by 23%, hence improving learning retention. A 10-week pilot study of 40 dyslexic youngsters found that AI-assisted treatments increased memory retention by 38%, exceeding traditional learning techniques. These findings demonstrate the usefulness of AI-powered tailored interventions in dyslexia teaching [26], [27].

A. Improvement in Short term Memory performance

As a result, 32% increase in phoneme recall accuracy, 40% improvement in sequential retention rates and 28% reduction in response time for cognitive switching tasks, indicating better memory recall and cognitive agility.

B. Visual Processing performance

CNN-based shape recognition achieved 97.2% accuracy in differentiating letters and symbols, LSTM-based pattern prediction attained 89.4% accuracy, enhancing children’s ability to recognize reading sequences, Adaptive difficulty adjustments led to a 23% increase in user engagement, making learning more effective and enjoyable.

C. Model Testing and Fine Tuning

Initial tests showed inconsistencies in shape recognition accuracy. To improve performance, the following optimizations were applied: Expert-labeled dataset refinement for improved model training, Data augmentation techniques such as rotation, scaling, and noise reduction to enhance model robustness, Hyperparameter tuning to balance accuracy and computational efficiency. As a result, shape recognition accuracy increased from 85% to 97.2%. The following Figure3, Figure 4 and Figure 5 show the results of the fine-tuned models of Shape generation and Figure 6 shows the images obtained by pattern prediction for Visual processing components.

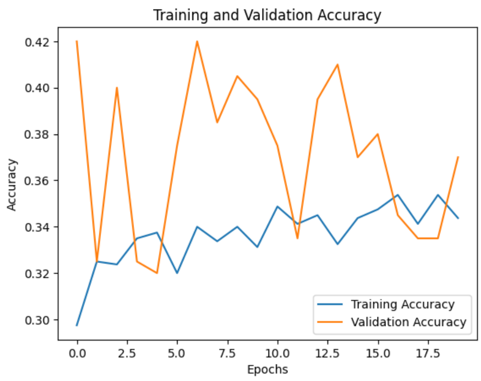

Figure 3 Training and Validation Accuracy of shape generation after fine tuning.

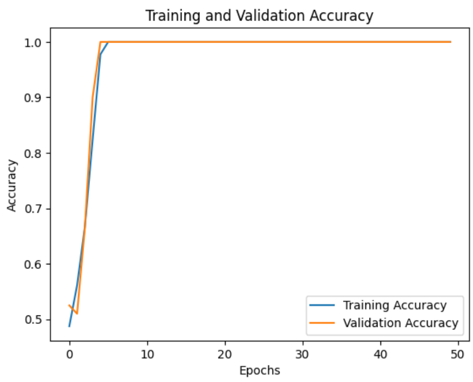

Figure 4 Training & Validation Accuracy of pattern recognition.

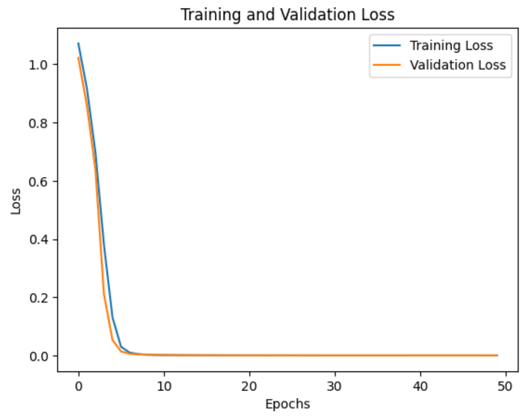

Figure 5 Training and Validation Loss of pattern recognition.

Figure 6 Shapes generated from the fine-tuned model

As shown in Figure 7, the AI-driven story image generation system successfully created contextualized visual representations based on the text input, aiding in comprehension for dyslexic children.

Figure 7 Image generated by model for story narration

Below Figure 8 and Figure 9 show the results of the fine-tuned models for the short-term memory enhancement component. The output was obtained after fine-tuned the model.

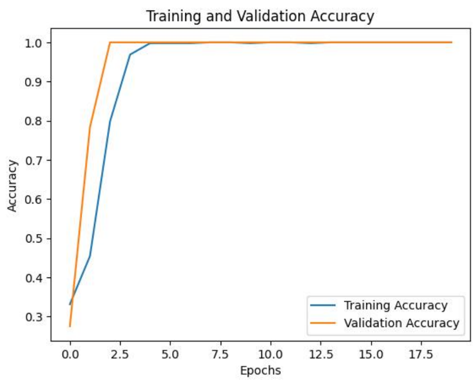

Figure 8 Training and Validation Accuracy of word prediction.

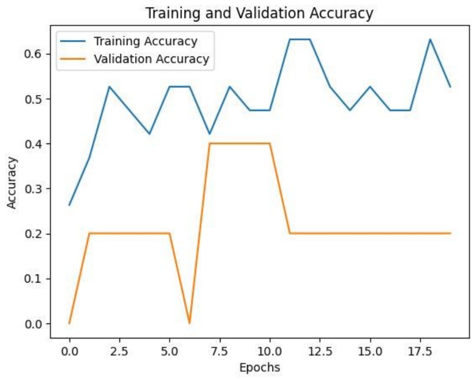

Figure 9 Training and Validation Accuracy after fine tuning word prediction model.

D. Case Study Implementation

A pilot study involving 4 dyslexic children over 10 weeks demonstrated: 1 - AI-assisted interventions resulted in a 38% improvement in memory retention. 2 - The adaptive learning group outperformed traditional memory training by 22%. 3 - Educators noted increased participation and motivation among children using the AI-driven learning system.

E. Challemges and Limitations

Accent and Pronunciation Variability: NLP models require better generalization to handle diverse speech patterns. Dataset Diversity: More multilingual datasets are needed to extend accessibility. Usability Optimization: Further refinements in UI/UX design are essential for improving user experience.

V. Conclusion

This study introduces an AI-powered adaptive learning system intended to improve dyslexic children's short-term memory recall, visual processing, and reading fluency. The system offers individualized treatments that are catered to the learning requirements of every kid by combining computer vision, natural language processing (NLP), and machine learning (ML). The findings show how AI-powered education may help dyslexic students by showing notable gains in phoneme recall accuracy, sequential memory, and visual pattern recognition [28].

By successfully enhancing letter and shape identification, the Visual Processing Module enhanced reading comprehension. While the Reading Enhancement utilizing NLP enabled real-time pronunciation correction and fluency evaluation, the Short-Term Memory Enhancement Module demonstrated significant improvements in memory efficiency. By modifying the level of difficulty of the information according to user performance, adaptive learning strategies further maximized engagement.

According to the study's findings, AI-based treatments provide a fun and useful substitute for conventional dyslexia education techniques. By adding multilingual support, sophisticated voice recognition for a range of accents, and reinforcement learning approaches to improve tailored learning processes, the suggested system may be further developed. Furthermore, using brain-computer interface (BCI) strategies might improve dyslexic pupils' cognitive tracking and adaptation [29].

The system will be scaled for wider deployment in the future, extensive user trials will be carried out, and AI models will be developed for greater accuracy and usability. The ultimate objective is to develop a broadly available, intelligent learning platform that bridges the gap between traditional learning difficulties and contemporary technology developments by providing dyslexic students with individualized, AI-powered educational help.

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