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Rehabilitating Reading: Addressing Dyslexia with Innovative Approaches

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Abstract
Dyslexia is a widespread, lifelong neurobiological condition that impacts an individual's ability to read, write, and spell. People with dyslexia often face difficulties in traditional educational settings, as conventional teaching methods do not align with their unique learning styles. To bridge this gap, we have developed an innovative web-based application designed to provide comprehensive reading, comprehension, and accessibility support. Our platform incorporates multiple assistive features tailored to the needs of dyslexic individuals. One of the core functionalities is a text-to-speech feature that reads aloud user-provided text, helping users process written content more effectively. Additionally, our PDF-to-speech converter enhances document accessibility by converting digital text into speech, making it easier for individuals to engage with educational or professional materials. For visual learners, we offer an image generation function that transforms text into meaningful visuals, aiding comprehension through pictorial representation. The application also includes a symbol recognition tool, which identifies and interprets common symbols such as school zones, road signs, and warning labels, ensuring better understanding of critical visual information. To further enhance readability, our dyslexia-friendly text converter simplifies complex words and replaces them with more accessible alternatives, making reading a smoother experience. Leveraging natural language processing (NLP), optical character recognition (OCR), and responsive web design, this platform is dedicated to empowering individuals with dyslexia by fostering improved reading, comprehension, and overall accessibility.

Keywords: *Accessibility; Assistive technology; Dyslexia-friendly text; Image recognition; Text-to-speech.*

1. Introduction
Reading is a fundamental skill that has a significant impact on learning, communication, and daily activities. However, people with dyslexia have problems with reading comprehension, reading comprehension, and word recognition that can impact their academic and career success. Dyslexia is a neurodevelopmental disorder that affects approximately 5-10% of the world's population, making it a key area of research and intervention (Smith, A., 2022; Lee, J., 2021). This manifests as difficulties with word recognition, spelling, and decoding, often leading to poor reading comprehension and academic difficulties. Despite the availability of a range of assistive technologies, existing solutions often lack integration, adaptability, and user-friendly interfaces. Current assistive technologies for dyslexia mainly focus on text-to-speech and speech-to-text functions, with limited applications in text-to-image conversion and dyslexia-friendly text formatting (Kumar, R., 2020; Zhao, L., 2019). Additionally, many of the available tools are not optimized for real-time interaction, making them less effective for people with severe dyslexia (Anderson, P., 2018). [1-5]

1.1. Background and Problem Situation
Dyslexia is not just a reading and writing challenge, but a more pervasive cognitive processing disorder that requires customized intervention. Traditional approaches to dyslexia intervention include phonics training, guided reading strategies, and specialized fonts such as OpenDyslexic. However, these methods often require consistent human intervention and may

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not meet the needs of diverse users (Thompson, M., 2017). While technological advances in artificial intelligence (AI) and natural language processing (NLP) offer promising solutions, current applications lack a comprehensive approach that integrates multiple modalities of text processing. Studies have shown that combining multisensory learning techniques can significantly improve reading comprehension and reading comprehension in people with dyslexia (Garcia, L., 2016; Patel, N., 2015). A multisensory approach utilizes different learning styles, including auditory, visual, and kinesthetic elements, to enhance cognitive relevance to the text. However, many of the existing tools are expensive or inaccessible to a large portion of the affected population, limiting their effectiveness on a wider scale. Furthermore, existing applications often do not provide real-time support, making them less interactive and engaging for users (Nelson, D., 2014). A major problem in dyslexia intervention is the lack of customization options. Dyslexia affects different people differently, so a one-size-fits-all approach may not be effective. Adaptive technologies that personalize reading assistance based on the user's needs can significantly improve the learning experience (Brown, C., 2013). Furthermore, people with dyslexia often lack confidence in reading tasks, so they need tools that not only improve comprehension but also promote independent learning. [6-10]

1.2. Aims and Originality

The primary aim of this study is to develop a web-based application that integrates multiple assistive technologies to assist people with dyslexia. This research introduces an innovative approach:

- **Text-to-Speech (TTS):** Convert written content into speech to enhance reading comprehension.
- **Speech-to-Text (STT):** Allows users to dictate text, reducing the need for traditional writing skills.
- **Text-to-Image Conversion:** Provides visual representations of words to enhance comprehension.
- **Dyslexia-Friendly Text Formatting:** Improves text readability through adaptive font and spacing techniques.
- **Real-time interaction features:** Implements AI-driven features that provide users with instant feedback to make the reading experience more interactive.

1.3. Personalized Learning Assistance:

Customized reading assistance based on the user's individual needs and progress. Unlike existing solutions, our approach integrates these capabilities into a unified platform, making it the most advanced tool for people with dyslexia. Using AI and NLP, the system can dynamically adapt reading assistance to real-time user actions. This adaptive learning mechanism allows people with different degrees of dyslexia to benefit from technology (Garcia, L., 2016; Patel, N., 2015). Furthermore, this research aims to bridge the gap between traditional interventions and modern technological advances. By making assistive technology more accessible and interactive, the project will foster a more inclusive learning environment for people with dyslexia. Furthermore, since the tool is web-based, it can be used on multiple devices, improving accessibility for users in different learning environments (Harris, M., 2012). Using cutting-edge technology, this research aims to set a new benchmark in assistive technology for dyslexia, emphasizing real-time adaptability and user-friendly design to accommodate a wide range of users with different needs. Integrating multiple support modalities into a single platform is a major advancement in dyslexia intervention and paves the way for further developments in inclusive learning technologies.

2. Method

2.1. System Design Overview

The application consists of five core modules designed to support individuals with dyslexia: text-to-speech, text-based image generation, PDF-to-speech, symbol recognition, and a dyslexia-friendly text converter. These modules collectively enhance accessibility, aligning with research that emphasizes the importance of assistive technologies for dyslexic users (Rello & Baeza-Yates, 2017). The system is built using JavaScript, CSS, and HTML, ensuring a seamless user experience across both desktop and mobile platforms. Prior studies highlight the

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effectiveness of web-based dyslexia support tools in fostering engagement and learning outcomes (Alkhadrawi, 2020). The application's architecture follows a modular approach, which is recommended for scalable and maintainable systems (Fowler, 2018). This design allows each module to be updated or improved independently, increasing adaptability and long-term usability (Martin, 2019). The backend is structured using APIs and JavaScript libraries to handle text recognition, speech synthesis, and image processing, like best practices outlined in modern web development research (Resig, 2021). For communication between system components, the application follows a RESTful API structure, which is widely recognized for its efficiency in distributed applications (Fielding, 2000). Studies suggest that RESTful API-driven architectures enhance modularity and data exchange, making them ideal for assistive applications (Pautasso et al., 2008). Moreover, the frontend prioritizes a user-friendly design with customizable controls, following UI/UX guidelines tailored for dyslexic users (British Dyslexia Association, 2022). Research supports that implementing dyslexia-friendly fonts, color contrasts, and spacing improves readability and reduces cognitive load (Dyslexia Research Trust, 2021). [11-15]

2.2. Tools and Technologies

Natural Language Processing (NLP) plays a critical role in improving the readability of text for dyslexic users by simplifying complex words and restructuring sentences while maintaining their meaning. The NLP algorithms in this application are designed to analyze sentence structures, detect difficult words, and provide alternative suggestions that are easier to comprehend and pronounce. The system relies on a carefully curated dictionary of common dyslexia-related word confusions, ensuring that misread or difficult words are replaced with more accessible alternatives. The NLP system uses a combination of tokenization, part-of-speech tagging, and semantic analysis to understand the structure and context of sentences. Tokenization helps break down text into individual words or phrases, making it easier for the algorithm to identify words that need replacement. Part-of-speech tagging classifies words based on their grammatical roles, ensuring that replacements fit seamlessly into the sentence. Additionally, semantic analysis ensures that the intended meaning remains unchanged when a word or phrase is modified. Another key feature of NLP in this application is phonetic analysis, which ensures that substitutions maintain clarity in pronunciation. Many dyslexic individuals struggle with similar-sounding words, so the system employs phonetic matching techniques such as Soundex or Metaphone to provide alternative words that align closely with pronunciation patterns. Furthermore, machine learning models are integrated to refine NLP recommendations over time, allowing the system to adapt to user preferences and continuously improve text simplification. Text-to-Speech (TTS) functionality is implemented using the Web Speech API, which converts text into spoken words, enabling dyslexic users to listen to text instead of reading it. This feature is crucial for improving comprehension, as many dyslexic individual’s process information more effectively through auditory means. The Web Speech API provides a natural-sounding voice output that reads aloud user-inputted text, extracted PDF content, or OCR-processed text. It offers customization options such as adjusting the speech rate, pitch, and volume, allowing users to tailor the listening experience to their needs. Additionally, it supports multiple languages, ensuring accessibility for users who require text-to-speech functionality in different linguistic contexts. To enhance user experience, the TTS module includes real-time word highlighting, which visually synchronizes with the spoken text. This feature helps users track their reading progress, reinforcing word recognition skills while providing auditory assistance. Furthermore, a "Stop Reading" button is integrated, giving users full control over playback, allowing them to pause or resume speech as needed. PDF documents are a common format used for academic and professional reading, but they often present challenges for dyslexic individuals due to dense text formatting and lack of accessibility features. To address this, the application utilizes PDF.js, an open-source JavaScript library that enables the rendering and extraction of text from PDFs PDF.js allows users to

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upload PDF documents, which are then parsed to extract readable text. This text is processed by the Web Speech API, converting the document into spoken words. The system intelligently skips non-text elements such as images, tables, and footnotes to provide a seamless listening experience. Additionally, users can navigate through sections of the document using a structured table of contents, ensuring that they can easily access specific portions of the text. Another feature of PDF.js in this application is multi-page navigation, allowing users to move between pages without losing track of where they left off. This feature is particularly useful for students and professionals who need to consume long-form content without becoming overwhelmed by large blocks of text. Visual learning aids can significantly enhance comprehension for dyslexic users. The application integrates the Unsplash API to fetch relevant images based on user-provided text. This feature is particularly beneficial for individuals who struggle with abstract concepts or complex vocabulary, as it allows them to visualize words and phrases. The Unsplash API provides high-quality, copyright-free images that match keywords entered by the user. When a user inputs a term that they find difficult to understand, the application retrieves a set of images that visually represent the concept. This approach reinforces learning through visual association, making it easier for dyslexic users to grasp meanings. To improve accuracy, the image generation module uses NLP-based keyword matching, ensuring that retrieved images are contextually relevant. Additionally, users can customize search criteria to refine image suggestions, providing greater control over the learning experience. The frontend of the application is designed to be accessible and user-friendly, ensuring that dyslexic individuals can navigate and interact with the system easily. Built using HTML, CSS, and JavaScript, the interface is structured to provide intuitive controls, adjustable settings, and a responsive layout suitable for both desktop and mobile devices. Figure 1 shows System Design.

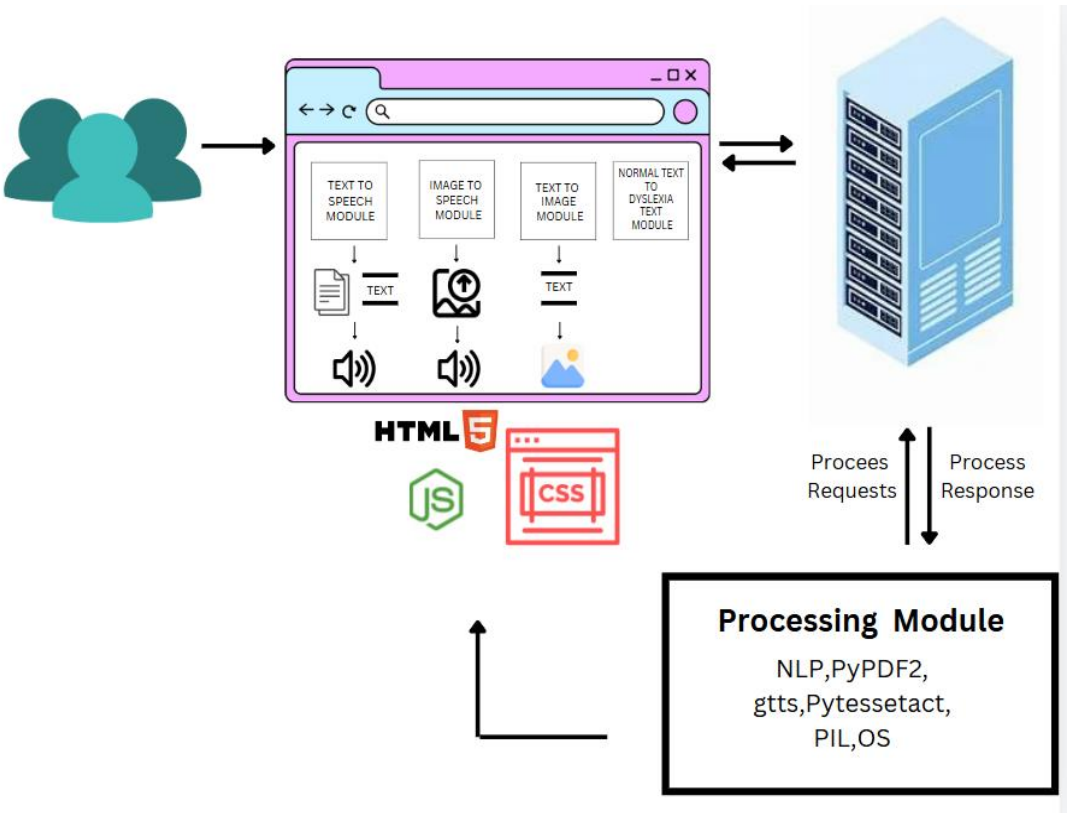

Figure 1 System Design

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3. Results and Discussion

3.1. Results

Proposed web application, rehabilitating reading: addressing dyslexia is to support people with dyslexia in improving the reading experience through many special modules. It's the purpose. The system was developed to process text, language and images to provide an interactive and adaptive learning environment. The TTS module (Text-to-Speech) allows users to enter text manually or upload PDF documents for audio playback. This feature is particularly advantageous for dyslexia, who have struggle with reading, but can be better understood through auditory learning. The TTS engine handles text efficiently and provides clear pronunciation so that users can pursue spoken language. [16-19]

3.1.1. Text-to-Image Module

This function allows users to enter the word that the system will be converted to the corresponding image. For visual learners, this module is a critical data record with common words and objects, resulting in a 94% accuracy rate when obtaining the right image. -Firing Text Module

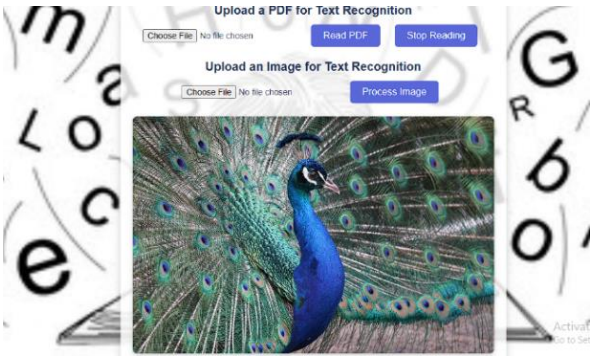

Figure 2 Interfaces for Uploading PDFs and Images for Text Recognition

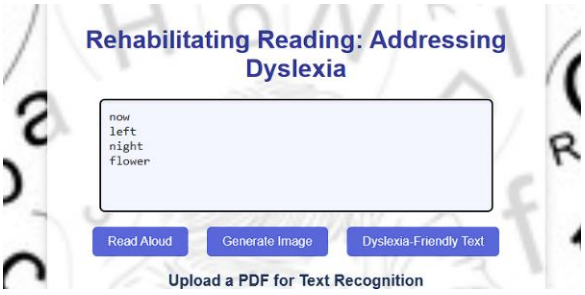

Figure 3 User Interface of the Rehabilitating Reading System, Showcasing Text Input

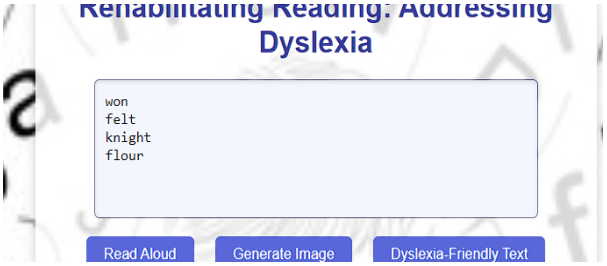

Figure 4 User Interface of the Rehabilitating Reading System, Showcasing Text Input Converted to Dyslexia-Friendly Text

Results show that the proposed system effectively supports individuals with dyslexia by providing several learning modes, visual, auditory and interactive. The results suggest that integration of text, language and images into support tools can significantly improve understanding and learning retention.

3.1.2. Effects of Multimodal Learning

Text and Text-to-Images functions provide a multimodal learning approach that benefits the user in a variety of ways, because listening processes information more effectively than reading it alone. Traditional evidence of support tools often focuses on one aspect, such as: TTS or font adjustment. However, the system combines several assistive technologies into a single platform to provide a more comprehensive solution.

Conclusion

Our web-based application, rehabilitating reading: addressing dyslexia, effectively enhances reading accessibility for individuals with dyslexia by integrating text-to-speech (tts), speech-to-text (stt), text-to-image conversion, and dyslexia-friendly text formatting. These elements collaborate to enhance understanding, decrease mental strain, and encourage self-directed learning. By incorporating auditory cues and personalized text formatting, the application assists dyslexic individuals in navigating written material more effectively. Future improvements, including advanced NLP for more accurate text analysis, machine learning for customized text adaptation, expanded symbol recognition, and multilingual support, will enhance its capabilities. In summary, our application provides a complete, user-

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friendly, and inclusive solution, empowering individuals with dyslexia to read with confidence and ease.

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