

ALEXZA: A Mobile Application For Dyslexics Utilizing Artificial Intelligence And Machine Learning Concepts

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Abstract—Dyslexia can be explained as a neurological learning disability which causes difficulties in reading, word decoding, comprehension, short-term memory, writing, spelling, and speaking. People who are diagnosed with dyslexia tend to show signs of low self-esteem and anxiety since they can't interact with the society in a way that their peers do. Many applications available in this domain help them by correcting their issues by playing games and reading some hard-coded texts or pdf books. This correcting process takes time and dyslexics become helpless when coping with their day-to-day activities. This paper describes results of an evaluation of a prototype mobile application which helps the dyslexic users to deal with their reading difficulties in real life successfully, while they are receiving proper treatments. This prototype can identify the texts around them and read it loudly so that user can understand and will be allowed to customize the chunking, scrolling and highlighting of words according to their disability levels. By integrating dictionary support with the phonic and morphological structure of the word, the user will be able to comprehend difficult and complex words easily. In addition, the study also explores the use of a machine learning approach to improve the effectiveness of the learning dyslexic complex words.

Keywords—Dyslexia, Image Processing, Text-to-Speech, Machine Learning, Dictionary, OCR, AIML

I. INTRODUCTION

According to the International Dyslexia Association (IDA), about 15% to 20% of the world population is recognized for having dyslexia regardless of their gender or ethnicity. It can be categorized into two main types; acquired and developmental. A dyslexic person might have born with this condition or acquired due to having brain damaged by accidents or stroke. Although these issues might affect a person's IQ level, people with dyslexia reported to have an average or above average IQ level [1]. However, these issues adversely affect a person's emotions and unable to recognize these symptoms early tends to subject the dyslexic individual to public embarrassment. Dyslexia can be explained as a neurological learning disability which causes difficulties in reading, writing and speaking.

- Visual-Spatial Difficulties - Have a problem in distinguishing between letters, syllabus and phrase orders and have a problem in reproducing them.

- Speech Sound Difficulties - Have difficulties in forming sentences and breaking words into syllables due to problems in understanding spoken language.
- Correlating Difficulties - Concerns more with difficulties in writing.

This research was mainly focusing on reading difficulties of dyslexia patients as reading plays a vital role in day to day activities as much as speaking. In this study, a mobile application prototype was developed to aid dyslexic individuals to read when they are engaging in day to day activities, with no age or disease condition limitation for the users. The main objective of the application would be to help them read quickly and accurately to carry out their daily tasks with ease and a much less effort. Reading a name board or a banner of a shop, a newspaper, instructions on a product packaged box can be identified as such tasks they need help with. This paper focuses on helping dyslexic users to deal with their reading issues in real life successfully since the existing implementations are more likely a long-term solution that cannot be used to produce accurate short-term results to help them in overcoming their disability.

II. BACKGROUND STUDY

A. Overview

According to J.G Guardiola [2], the accuracy and the speed of single word identification determines efficient reading; and dyslexics have mainly a phonological deficit that consequently hurts their word recognition skills, and this later affects negatively on their reading comprehension, vocabulary, and even intelligence [2]. Researchers like John Rack and Richard Olson, psychologists from the University of Colorado, showed that dyslexics are slower than normal people in rhyming tasks, and they have difficulties matching speech sounds to their respective letters [2]. There are few issues identified as the main symptoms of the disease. Most dyslexics seem to have phonological issues which makes them slow or inaccurate when reading pseudo-words. Another symptom is having a short-term memory. It does not imply that each and every person who suffers from short-term

memory does have dyslexia, but there is a strong possibility of having [2].

The role of genetics in Developmental Dyslexia(DD) has been highly recognized lately and many researches have been conducted regarding the possible downstream effects of risk genes on the brain structure, function and circuitry [3]. Most recent studies [2] show a tendency to focus more on computer-based learning models to supplement traditional teaching method that commonly uses a pen, paper or any material, which apply multi-senses application for students with dyslexia. There are many studies conducted on identifying a creative learning technique to help dyslexics. Luz Rello, being a prominent figure, has published several key research papers focusing on areas such as layout guidelines for web text [4], usage of short words and frequent words [5] and how graphical schemas usage affects dyslexics [6].

Many apps that already exist, help the dyslexic patients with correcting their issues by playing games and reading some hard-coded texts or pdf books [7]–[9]. These apps help with the identification of the defect and long-term solution, which is not that much of a use for day-to-day routine activities. However, by making use of e-readers and phones; significant improvements can be seen in dyslexic patients [10]. Therefore, there can be seen much research conducted regarding utilizing mobile apps to help even one single aspect of dyslexia.

Evolution of mobile applications for the dyslexic community has become more innovative in the modern era. Through a wide range of assistive technologies, their learning mechanisms have been improved and evolved. Out of the different kinds of applications and tools that were introduced, designed and developed by various researchers; there are applications in diagnosing dyslexia, training such patients in reading, e-learning based systems, and gamification platforms.

B. Existing Applications

Dyslexia Baca(DB) is a mobile application developed in Malay, providing a learning tool for children suffering from dyslexia. DB is designed and implemented by addressing the problems of difficulties faced by dyslexic children in recognizing and memorizing the alphabet. Its main objective was to motivate such children to read by recognizing the alphabet and practicing recalling of learned information.

It is said to be a user-friendly and supportive learning tool, which provides visual graphics for confusing letters (*such as p, q, b, d, m, and w*) alongside with a series of games to play. Aiding to differentiate the dis-similarities between the letters was the main aim of this application.

As they have trouble in processing information by looking at a word, connecting the sound made by a specific letter or deciphering the sounds of all the letters together that form a word, [11] the conventional teaching approaches are not suitable for them. Thus, the application is based on advanced technologies such as touchscreens, accelerometers, gyroscopes and voice recognition. Visual, auditory and kinesthetic approaches are said to be appropriate and suitable for teaching

dyslexic children. Hence the app has adopted a multisensory approach to making it more worthwhile.

Furthermore, given statistics recorded a total of 4096 downloads of the application among various countries with USA, UK, and Malaysia having higher percentages. Therefore, this app can be considered as a practically proven potential path for such children to learn how to read, as reading is based on repetition of recognizing and memorizing letters of the alphabet [12].

Another application was developed by a group of Portuguese researchers to help the disabled to practice reading and achieve fluency and accuracy. As medical treatments are costly and the disability has an adverse effect on the children's academic lives, the application is aimed to train them to improve their reading as well as writing. This application is developed in their mother tongue and it applies the patients' visual, hearing and phonological skills in order to improve their reading and writing [13]. The functionality of the app is making available a random word to the user and get their speech feed and match it with the corresponding word. Each word has five trials; once the user gets it right a new word will be given. The words will be selected randomly and the time taken by the user to speak out the word will be measured.

Several tests were conducted to measure the accuracy of the application by using diagnosed and non-diagnosed people. As the article stated, "Although the initial results of reading training being potentially interesting, the effectiveness of the application in this context should be assessed and monitored along a relevant period of tests." [13], the researchers themselves mentioned even though the primary stage of testing used to be promising it is vital to keep on testing to verify the complete effectiveness of the application. The research concluded by suggesting that it is important and viable that another research should be carried out in this domain as a study and verification of effectiveness in dyslexia training applications.

Moving on to other applications already exist by conducting researches regarding this aspect, 'Dyslexia Friendly Reader' application and the exploratory study can be identified as another prominent approach. It is mainly focused on overcoming the limitations of existing reading apps and present a prototype with more significant features.

The specialty of this app is that they have addressed the issue using a different angle than the above apps, concentrating on font color, font size, font style, background color and a number of words displayed at a time. The research focuses on the application and exploration of knowledge about fonts, color schemes, and text formatting. Several other types of research also have identified the benefits of using e-readers through the reduction of the amount of text displayed that accompanies. With the increase in text size and there have been some preliminary suggestions that the timed display of text in small chunks (as small as individual words) presented in speed reading applications can be of benefit as well [14].

Moving to the Dyslexia Friendly app that was proposed, it has mainly suggested three modes namely listening, chunking and guidance. The listening mode has the possibility of

accessing text and their pronunciations via text-to-speech functionality while it is said out loud the corresponding displayed texts will be highlighted accordingly for the easy navigation of the auditory feed. Furthermore, regarding the auditory feed, additional features such as customizing speed, pitch, volume, and voice are integrated.

Similarly, the second mode chunking and auto scrolling provided the ability to control the amount of text displayed on the screen at once, and scrolling could be done automatically synched with the audio feed. The ability to change the auto-scrolling speed, the capability to choose the chunk size was added as extra features for further support.

Finally, the guidance mode consisted of lexical support with dictionary integration to learn unfamiliar complex words and instructional support the practice of reading activities and their associated skills such as skimming and scanning [14]. Ultimately the study concludes by stating that a simple interface focused on immediate results through text-to-speech has proved very popular [14] and the customization of text display increases the easiness to access to the text.

Linking the two fields of games and education is said to be a fruitful mechanism to get effective results from the students. Thus, having applications relating both of them within the scope of helping dyslexic children, is another aspect that the researchers have considered. Going further into the usage of gamification platforms to support dyslexic children, a group of researchers from UCL educational institute, London, has conducted research regarding this aspect.

This paper explores how gamification could potentially benefit a specific student population, children with dyslexia who are transitioning from primary to secondary school [15]. Classdojo, the gamification platform was analyzed via this research and was tested in the classroom in their teaching sessions. The main objective of the study was to motivate the kids with reading disabilities, hoping the gamification approach would be beneficial to overcome their struggles.

The most commonly employed aspect of gamification is the use of an achievement system, often in the form of badges or rewards [15]. The platform Classdojo being a gamification system that uses real-time feedback, it allows the teacher to create badges of rewards as they see fit. Other than the badge rewarding, the next important component of this platform is its reporting system, where the progress will be automatically emailed to parents on a weekly basis. A test was done using two dyslexia specialist teachers with seven different students, letting the teachers run their own sessions and interviews were held with teachers, parents, and students to see whether the students were motivated, and what their improvements were. As the article itself stated, even though the sessions were tailored according to the teacher, the research proved that the use of gamification can be beneficial in motivating the students in the dyslexic community.

Moving on to the identified e-learning based systems that were designed to aid and support dyslexic community, a dyslexia adaptive e-learning system, research carried by a group of researchers in the Middlesex University of London showed the importance of this approach.

It was focused to address the shortcoming of traditional e-learning systems not being adaptive. The new system is user-centric and interactive based on information about the user's learning preferences [16]. This system followed a multilayer architecture having five different layers namely presentation, adaptation, learning management system, application server and database layer facilitating different functionalities to the system. The learning management layer was to provide all processes, tasks, and resources to support the learning process whereas the adaptive layer provides the adaptive functionality to the system.

As the existing traditional apps merely presented the disabled students only with direct instructions, and as it was not effective and the systems lack necessary interactivity [16] those were not suitable enough to serve the purpose of aiding the patients properly. The newly designed app was identified with new features that supported adaptivity so that the learning content can be customized according to the preference of the user proving that it was, in fact, more useful to the dyslexic community than the existing e-learning based apps.

C. Existing Applications With Comparison

TABLE I. COMPARISON OF SIMILAR APPS

Features	Existing Applications					ALEXZA
	Natural Reader	Dyslexia Baca	Dyslexia Friendly Reader	Google Play Books	Cool Reader	
A mobile application	✓	✓	✓	✓	✓	✓
TTS with voice controls & navigation	✓	✗	✓	✗	✗	✓
Text highlighting	✗	✗	✓	✓	✗	✓
Auto scrolling	✓	✗	✗	✓	✓	✓
Text formatting	✗	✗	✓	✓	✓	✓
Capture live feed	✗	✗	✗	✗	✗	✓
OCR (convert images into texts)	✗	✗	✗	✗	✗	✓
Dictionary support with phonic and morphological structure	✗	✗	✓	✗	✗	✓
TTS facility for dictionary	✗	✗	✗	✗	✗	✓
Suggest easy, similar words	✗	✗	✗	✗	✗	✓
Process long texts	✓	✗	✗	✓	✓	✓
Word chunking	✗	✗	✗	✗	✗	✓
Customization of features	✗	✗	✗	✓	✗	✓

D. Recommended Features

Following that, the study has identified the following features as the requirements in an ideal reading app for individuals with cognitive impairments [16].

1. Text-to-speech interface with navigation and voice controls.
2. Accessible text style settings with sensible presets.[17]
3. Outline-based navigation.
4. Bookmarking, highlighting, and annotations.
5. Chunking interface to display the text in smaller segments, including auto scroll.
6. Additional advanced reader settings not mixed with basic settings.
7. Library and access to online repositories of texts.

III. METHODOLOGY

The system provides the user with an opportunity to overcome the reading difficulties by simply using camera option in the developed app. Then the mobile application will identify the texts in the live feed and then read it loudly so that user can understand (Text-To-Speech). Those identified texts will be displayed as only small chunks of text at a time to reduce distraction and the user will allow full control of text display, such as the choice of font, font size or test/background color combination. Listen mode will highlight sections being read and allow for an easy navigation of the audio. To help the users with unfamiliar or complex words, dictionary support with phonics and morphological structure of the word was implemented [18]. These complex words per user will be mined and will suggest a reader with a similar or an easy word next time the user comes across those words. In order to make them understand words easily, text amount was minimized and images were added wherever possible. Fig. 1 shows the overall architecture and flow of the system.

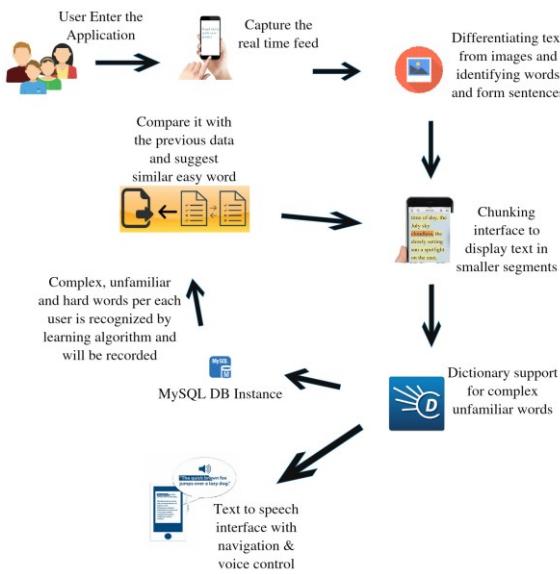


Fig. 1.

Overall Architecture

A. Optical Character Recognition

The camera was integrated into the system to capture the real-time feed in order to enable the user to engage with the surrounding through the application. The feed was sent through an image pre-processing algorithm, Canny edge detection using OpenCV, to enhance the quality of the feed. The Google Vision API with Text Recognizer API was used to differentiate text from images and identify words and form relevant sentences.

B. Chunking

Word chunking facility is provided to the user to segment the camera captured words into chunks of user preferred word counts. Text formatting techniques such as size change, font-style change, and color change along with background formatting are provided for users to choose according to their preference. Default values will be provided for all manipulations choosing the most generic dyslexic friendly values. Finally, the fully manipulated text output will be displayed on a separate screen.

C. Text-to-Speech with Voice Controls and Navigations

Text to Speech facility is provided for the users to overcome the reading disability. Chunked words that are displayed on the screen will be converted to Text-to-Speech. Voice control settings such as pitch adjusting and speed adjusting are provided for the users to choose according to their preference. Navigation options such as play, stop, forward and backward play options are provided for the users to read the text with ease. Furthermore, Text-to-Speech facilities are supported for the dictionary integration.

D. Text Highlighting and Auto Scrolling

While the texts that are been read through Text-to-Speech, text highlighting happens to make it easy to read the words for the users, and the auto-scrolling feature is integrated to make the reading more user-friendly.

E. Dictionary Integration

This component is added to aid the users to help in understanding complex words they come across. It is implemented in both ways where the user can type a word and find the meaning or long press word in final output screen and get redirected to the dictionary, where it offers the meaning of the word, phonetic spellings, and notations along with proper pronunciations. Relevant images that will depict the correct meaning of the word will be displayed where that part is achieved through image classification machine learning technique.

F. Machine Learning

In this feature, complex and unfamiliar hard words for dyslexic users are identified from the captured feed and it suggests an easy similar word for that. Hard words describe the words potential dyslexic people most commonly have problems with when reading.

The authors have used a feedforward neural network for text classification to identify hard words; two layers of neurons and a "bag of words" approach to organize the training data which belongs to two classes, easy and hard. Even though algorithmic approach using multinomial Naive Bayes seems effective, it suffers from few fundamental flaws; the algorithm produces a score rather than a probability. In here we want a probability to ignore predictions below some threshold.

Neural network training function creates synaptic weights using matrix multiplication. A neural network model is created containing all our synaptic weights for the training data and it can be improved by adding words, identified by the user while using the application. User can suggest hard words while using the application, this way training data is collected, and the model will be recalculated.

TABLE II. CONFUSION MATRIX

n=200	Predicted: Hard	Predicted: Easy
Actual: Hard	63	32
Actual: Easy	21	84

G. Smart AI Assistant

This feature was integrated into the system in order to give the user to quickly resolve their issues which they face while using the application. The core of this AI was based on Artificial Intelligence Markup Language (AIML).

```
<?xml version="1.0" encoding="UTF-8"?>
<aim1>
    <category><pattern>HOW CAN I LISTEN *</pattern>
        <template> You can listen to captured text by
            1.)Capture the text.
            2.)Click the send button.
            3.)Now you can click play button to listen to the captured text.
        </template>
    </category>
</aim1>
```

Fig. 2. Sample AIML Code Snippet

Here, Fig. 2 shows the code snippet which performs the function where the user will be able to get help from the smart bot regarding functionalities of the app and the Fig. 3 shows a sample algorithm which helps the bot to learn and remember while chatting with the user.

```

<category>
  <pattern>* IS A *</pattern>
  <template>Okay, I will remember <star/> is a <star index="2"/>
    <think>
      <set name="isaname"><srai>ISANAME <star/></srai></set>
      <condition name="isaname">
        //
      </condition>
    </think>
    <learnf>
      <category>
        <pattern> <eval><get name="learnpattern"/></eval>
          <eval><star index="2"/></eval>
        //
      </pattern>
    </category>
    //
  </learnf>
</template>
</category>

```

Fig. 3. Bot Learning Algorithm

IV. EVALUATION RESULTS

The Fig. 4 shows the prototype developed to aid the dyslexics. The testing was carried out with five dyslexic participants and the reactions of them were positive due to the simplicity of the design and having many features integrated into the application without complicating the design. The majority chose the word count between 5-10 words which led the authors to believe that it is the word count that the users are comfortable with. Furthermore, the mostly used foreground (*font color*)-background color pairs were yellow/black and cream/black.

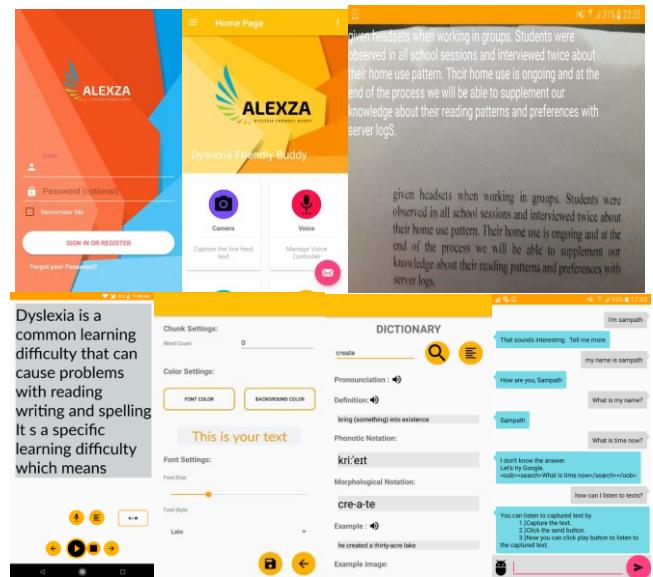


Fig. 4. Prototype

Most Dyslexic patients chose a pitch rate between 40-55 which is familiar to a human voice and chose a speed rate between 10-55, a slower rate to read the words. Majority of users preferred having auto-scrolling feature since it made them use the app in a friendly manner. Most users reacted positively with text highlighting while been reading.

Google Vision API's average accuracy lies around 90% for text detection and with the results gathered from research, confirms that accuracy will improve with the quality of the image. By using a combination of algorithms from the OpenCV library, video feed was filtered before going through the text detection using Google Vision API. First, the feed was sent through a filter to remove background noise and then Gray and Canny edge detection algorithms to remove the background and detect the text area of the image feed. Fig. 5 shows the intermediate filtering process and Fig. 6 shows the final detected text.

Abstract: Dyslexia can be explained as a reading disability which causes difficulties in reading, decoding, comprehension, short-term memory, writing, and speaking. People who are diagnosed with dyslexia show signs of low self-esteem and anxiety since they can be with the society in a way that they peers do. What is available in this domain helps them by correcting that playing games and reading some handwritten texts or this correcting process takes time and dyslexics have to cope with their day-to-day activities. The research results of an evaluation of a program application which helps the dyslexic users to do problem issues in real life successfully while the

Fig. 5. Intermediate Filter

Abstract: Dyslexia can be explained as a neurological learning disability which causes difficulties in reading, word decoding, comprehension, short-term memory, and orthographic spelling. People who have dyslexia often have trouble learning to read, writing, word signs, and numbers. Dyslexia is a specific learning difficulty, spelling, with the severity of symptoms ranging from very slight to severely impaired. Dyslexia is a life long problem and can interfere with one's ability to learn and succeed in school. There are many ways to help people with dyslexia. One way is to use computer programs that can help them learn to read and spell. Another way is to use assistive technology such as text-to-speech software, speech recognition software, and screen readers. These tools can help people with dyslexia access and understand written text. Another way is to use multisensory teaching methods, such as kinesthetic, auditory, and visual approaches. These methods can help people with dyslexia learn to read and spell by using different senses. Another way is to use explicit, systematic, and structured reading instruction. This type of instruction focuses on teaching decoding, fluency, and comprehension skills. Another way is to use research-based interventions, such as Orton-Gillingham, Wilson Reading System, and Dyslexia Reading Program. These interventions provide individualized instruction and support for people with dyslexia. Another way is to use accommodations, such as extra time, assistive technology, and modified assignments. These accommodations can help people with dyslexia succeed in school and in life. Another way is to use positive reinforcement, such as rewards and praise. This can help people with dyslexia feel successful and motivated to learn. Another way is to use family and community support. This can help people with dyslexia feel supported and encouraged to succeed. Another way is to use professional support, such as speech-language pathologists, educational psychologists, and special education teachers. These professionals can provide specialized services and support for people with dyslexia.

Fig. 6. Detected Text

In the hard word detection process, sigmoid function was used to normalize values and its derivative to measure the error rate. With an increasing number of iterations, we could get an error rate which was acceptably low. Fig. 7 shows the error rate reductions according to iterations.

```
Training with 20 neurons, alpha:0.1, dropout=False
Input matrix: 50x50      Output matrix: 1x2
delta after 10000 iterations:0.004804217653907966
delta after 20000 iterations:0.003265053455547647
delta after 30000 iterations:0.0026115203938360003
delta after 40000 iterations:0.0022308244642299975
delta after 50000 iterations:0.0019750693413491237
delta after 60000 iterations:0.0017884927069325022
delta after 70000 iterations:0.0016448423372112087
delta after 80000 iterations:0.0015299471613820165
delta after 90000 iterations:0.001435406288927963
delta after 100000 iterations:0.0013558864258841927
saved synapses to: synapses.json
```

Fig. 5. Error rate with iterations

V. CONCLUSIONS AND FUTURE DIRECTIONS

This paper has presented a study of improving the day-to-day reading ability of the dyslexics. Users feedbacks and the prototype preliminary testing confirmed that the research was successful. Although, there are many reader applications, the features which presented to the dyslexics by this prototype were yielding results already. Having many features which can be customized according to their disability, let dyslexics who normally very reluctant to read texts, engage with their surrounding easily and more enthusiastically. There were few suggestions for future work gathered from the observations while testing.

1. Adding localization for OCR, Text-to-Speech, and Dictionary functionalities where it can be further improved by having the ability to detect Sinhala and Tamil texts.
2. Smart AI Assistant can be improved to communicate with the user with speech instead of texts. This can also be improved as a teaching assistant for the dyslexics. For an example, giving dyslexics directions to how to pronounce a word correctly and check if they pronounce it correctly.

There are quite a few research and development left to be done regarding improving the reading ability of dyslexics but our work demonstrates and proves that the idea is viable, achievable and outlines some of the future directions that this research can be extended.

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