Dyslexi Duo: Design and Implementation of a comprehensive solution for Dyslexic Students

Dr. R. Deepalakshmi, B.E, M.E, Ph. D.[a],
Shanmuga Priya M[b],
Sneha S[c],
Janani Priya T K[d],
Srivarshini S[e]

[a]Computer Science and Engineering, Velammal College of Engineering and Technology, Madurai, India;
[b]Computer Science and Engineering, Velammal College of Engineering and Technology, Madurai, India;
[c]Computer Science and Engineering, Velammal College of Engineering and Technology, Madurai, India;
[d]Computer Science and Engineering, Velammal College of Engineering and Technology, Madurai, India;
[e]Computer Science and Engineering, Velammal College of Engineering and Technology, Madurai, India
rdl@vcet.ac.in[a] shanmugapriyashanu2002@gmail.com[b]; sneha23cse@gmail.com[c]; jananipriyatk@gmail.com[d]; srivarshinisuresh@gmail.com[e];

Abstract

The prevalent learning disorder, dyslexia impair a person's capacity for reading, writing, and spelling. But with the aid of successful interventions like multisensory techniques, phonics training, and assistive technology, persons with dyslexia can improve their reading and writing skills and excel in school and in daily life. This research paper 'Dyslexi Duo' is a comprehensive solution for dyslexic students in all age group and includes 3 major sections. A Super Pad for the age group >18 to help them read digital documents like pdf with ease. An Interactive & Educational game - Hydra Hunt for the age group of 4-10 to learn formation of words with letters using both visual & auditory techniques. This game incorporates 4 key elements: storyline, clear goals, multiple levels, and points. An attached mobile application 'Alpha360' for the age group of 3-8, which is an interactive multimedia learning app using 3d viewing, Text to Speech, Speech to Text technology which acts as an effective multisensory approach. This entire application was tested & evaluated with dyslexic students of the corresponding age group. Overall, our application can be a one stop solution to help dyslexic students overcome their challenges at an earlier age and achieve academic success.

Keywords: dyslexia; multisensory methods; assistive tools; interactive multimedia learning app; 3d viewing.

(1) Introduction:

According to English Oxford Living Dictionaries the word 'dyslexia' is defined as 'a general term for disorders that involve difficulty in learning to read or interpret words, letters, and other symbols, but that do not affect general intelligence'. Dyslexia results from individual differences in the parts of the brain that enable reading. Dyslexia appears to be linked to certain genes that affect how the brain processes reading and language. From the given statement, it is obvious that a person with dyslexia will struggle with reading disorders. Reading is a necessary ability for all students to succeed in

school, so the issue of dyslexic students, unable to identify, retain, and comprehend a character during the reading process is taken into serious consideration. Several studies have shown that people have difficulty in reading where digital documents is not an exception. To combat this, several studies were conducted,

A study was done to look at the impact of different text formatting techniques on readability, Daniela Traficante, Laura Giordano, and Giovanna Mazzotta (2020) conducted a study with 128 participants (64 with dyslexia and 64 without dyslexia). Reading speed and accuracy for those with dyslexia were found to be greatly improved with more space between letters and words. The study highlights how crucial it is to employ various text formatting strategies to increase text readability for those who have dyslexia. Another study by Sierra Laddusaw and Jeremy Brett (2019) found that incorporating the Open Dyslexic font in exhibit materials at Cushing Library improved access for dyslexic visitors. A 20-page guide was available at the exhibit entrance to provide the same information as Non dyslexic visitors. The results of adding Open Dyslexic font to the exhibit were positive. The study by Boniface et al. (2021) examined the effects of text-to-speech technology on rates of mind wandering in students with dyslexia (20) and typical development (50). Participants were presented with texts in two modalities: self-paced silent reading and text-to-speech reading. The results showed that both groups had better comprehension and reduced rates of mind wandering in the text-to-speech condition. Sweep Sweep Spell technique by Ronald Dell Davis is a native approach in which students are usually instructed to hide the words they are reading with a finger and slide the finger by one letter then it continues from reading out each letter loud to the whole word. Dyslexics often struggle to recall details from reading, such as where they left off. Ronald Dell Davis developed a native technique in which he taught dyslexic individuals how to use a slit in a piece of paper to conceal words or letters in a line. so that readers don't get confused about where they left off.

Currently, there are numerous approaches that benefit them. Many web technologies have emerged to support them. Luis Otávio de Avelar, Guilherme Camillo Rezende, and André Pimenta Freire from Universidade Federal de Lavras, Brazil involved the design and implementation of a prototype browser extension for dyslexic users called Web Help Dyslexia, intended to assist in making web material more readable for people with dyslexia. The application has options for modifying the font size and type, stripping away text decorations, altering the foreground and background colors, and finding synonyms for words. Preliminary evaluations with dyslexic users showed that the features to help concentrate when reading and considered very useful. Apart from this, several browser extensions have been developed to assist people with dyslexia in reading web pages, as reported in multiple studies. These extensions enable users to modify various aspects of web pages to make reading easier, such as font type, font size, letter spacing and word spacing (e.g., Open Dyslexic for chrome, Dyslexia Reader Chrome, Dyslexia Friendly and Helper bird, Helper Bird stands unique and provide additional features to contrast between text and background colors and line ruler. These results imply that the use of such tools can greatly enhance dyslexic readers' reading abilities and have important implications for educational and professional settings.

The previous studies that were mentioned in the above context focused solely on the customization of web content using a Chrome extension. None of these studies addressed the issue of making digital documents, such as PDFs, more accessible to individuals with dyslexia by implementing dyslexia-friendly features. Although Helper Bird allows for the upload of PDF files, its features are limited and requires a subscription, making it inconvenient and inaccessible for many users. Additionally, all the extensions mentioned above only offer one standard voice for their text-to-speech function, which lacks customization. None of these extensions include the "slow reveal" feature, which was inspired by Ron Davis's “Sweep Sweep Spell” method and a Color Differentiator tool for similar letters like b and d.

The British Dyslexic Association estimated that 10 percent of the population are dyslexic, with 4 percent are severely affected. To aid them various interventions were introduced yet they suggest that

learners or practitioners consider phonics to be the best approach. But there is an issue that there will be lack of involvement. Specifically, to gain their interest VAKT (Visual, auditory, Kinesthetic and Tactile) has been introduced which uses a Multisensory technique this technique has shown increased engagement and achieved a promising result with students in learning. Another study by Siti Khatijah Nur Abdul Rahim and Nur Hasni Nasrudin (2018), stated that if the multi-sensory method was adopted in learning strategy it could help dyslexia. The learning strategy refers to teaching dyslexia persons more than one of the five sense like tactile method and visual memories. Here dyslexia persons are advised to write letters on the surface like sand or using clay. With this method the students can remember visual memory of letters and sound of the letters. Augur and Brigger developed Hickey Multisensory Language Course program. They understood the significance of learning the alphabet in order. They provided three main activities, and these three activities make them remember the alphabets sequentially. This program includes visual, auditory and tactile methods which are more useful in remembering letters and words. The reading and spelling training mainly focuses on maintaining the relationship between sound and symbols. They concluded by using visual and auditory method students can be able to achieve the basic level of reading. Nowadays, mobile devices and other electronic devices are playing a vital role in learning. The use of mobile app learning in education has created a platform to gain their knowledge. According to a study by Stratigoula Politi-Georgousi, numerous mobile apps have been designed and developed to assist them with specific learning skills such as reading, writing, spelling etc.

A preliminary study was undertaken by Jorge Buele, Victoria M. López, L. Franklin Salazar, Jordan-H. Edisson, Cristina Reinoso, Sandra Carrillo, Angel Soria, Ral Andrango, and Pilar Urrutia-Urrutia (2020) on an interactive system to improve the skills of children with dyslexia. Another study was conducted by Aleksandra Sholdova (2020) on how educational games can benefit dyslexic children. They found that multi-sensory learning style using interactive games can potentially enhance the learning process, making it easier to acquire and comprehend the material. A study by James Ohene-Djan and Rahima Begum introduces The Dyslexia Activity System (DAS), an online learning tool that makes use of multisensory learning to give dyslexic students a fun learning environment in which to pinpoint their reading, writing. Study by Maria Rauschenberger, Luz Rello, Ricardo Baeza-Yates with students of age from 7 to 12 introduces a web-based prototype to screen pre-readers.

Many programmes with capabilities like backdrop and font customization, text-to-speech conversion, differentiator, and several chrome extensions with all four of these features have been created as a result of these findings. Despite the fact that each of these abilities can be used independently, dyslexics find it uncomfortable to use frequently. Online access to the native sweep sweep spell and line-cursor approaches is not possible. The digital world has taken over in modern times. We don't have a feature to read digital documents like pdfs, even though there are many capabilities available to facilitate web-based reading. We therefore created a tool to assist them in reading PDF with lot of customization. Many studies have shown that multisensory learning techniques, which use more than one sense at once, are most effective for rehabilitating dyslexics. Yet because it has only natural/native method, sand or clay, which some people may be allergic to, is used. Native method is also time consuming, and it is difficult to use it.

Dyslexics need to understand and sustain today's internet as well, but it is not convenient for them to utilize it like other people do. So, we developed a compact web app called “Dyslexi Duo” which comprise of 3 major features “Super Pad”, “Hydra Hunt”, “Alpha 360”. The approach of these features is thoroughly explained in Section 2. The functions as well as the outcomes of our application "Dyslexi Duo" are covered in Section 3. The results that are derived are included and explained in Section 4. The significance of the application is concluded in Section 5. References are provided in the final section.

(2) Methodology:

(2.1) Participants

Classroom: Participants from this study were recruited from a certified center located in Madurai. This center is publicly funded and the following tuition-based-classes-rooms: (1) 11 to 17 years old (2) 4 to 7 years old (3) 3 to 5 years old. All teachers were staffed with a licensed childhood educator. The criteria relevant to this study are as follows: (a) To determine the learning objectives for each kid, a curriculum was in place. (b) Outcomes for all children were analysed and measured using a validated kit. (C) data were collected on all children's learning outcomes. It is noted that there was not an established tiered support system, instead the teachers were encouraged to instruct each child. The classroom teachers used traditional methods practices and various assessment within classroom activities with a combination of teacher and child led activities. There was a proper classroom atmosphere for the children to learn enthusiastically and interaction between the children and teacher were in person to person as per the past relevant study.

Teachers: After reaching out to the center, our team gave a presentation about the study during the meeting with teachers. All teachers were properly trained to train the children with the following instruction. Prior to the presentation four teachers volunteered to participate in this study. The four teachers were led by different children of different age groups. Two teachers train children of the age group 3 to 5 years using tactile, a traditional method. The other two teachers train the children of the age group 4 to 7 years to practice reading.

Students: A study was conducted nearly with 15 participants of different age groups, there were different features in our web tool as we mentioned, and we gave our web tool to use for gaining the result or feedback from the student.

We interacted with the students to collect their level of difficulty to study with the help of their mentor and we also explained our features that we developed. We tested our feature “Super Pad” for the age group between 11and 18, we made them use the features available in the super pad with the help of their guide. While interacting with them we get to know about their difficulty in learning and reading. We helped them and asked them to try to read the line of a paragraph that is extracted from the pdf and applying all the special features of super pad to make them read.

We also had the age group between 4 and 7 and we interacted with them to get to know their difficulty. We found out that some are struggling to read the alphabet, and some are struggling to read the two or three letter words. We made them use Hydra Hunt that we developed as a game to make them identify letters as some can identify the letters. This is the game where fish holds the letters, and the student must frame the word that they hear in audio. Some tried finding the letters and frame the words.

For the students who were struggling to identify the alphabet we made them try another feature called Alpha360 for the age group between 3 and 5. This feature was the alphabets were shown in a three-dimensional way as we mentioned. We made them try the feature with the help of the guide and they tried learning the alphabet.

(2.2) Procedure

Our application is used by people with dyslexia who have difficulty reading and writing. The features are basically categorized into two. Super Pad and Hydra Hunt is developed using Full Stack Web Development in which Frontend Stack includes HTML (Hypertext Markup Language), CSS (Cascading Style Sheet), JS (JavaScript), Bootstrap, jQuery and Backend Stack includes Python with Flask Framework. Alpha 360 is an android application developed using flutter, cross-platform mobile app development and Dart programming language is used. This app can be easily downloaded from

Play Store. The Quick Response (QR) code will be attached on our website Dyslexi Duo that will navigate you to the Play Store to download the app at user's convenience. Users may navigate to the desired functionality quickly since the features of our application are prominently displayed in the navigation bar on the website's home page. Information about dyslexics globally is available on the landing page. We suggested three primary aspects in light of all of these. Alpha360, Hydra Hunt, and Super Pad. As users enter our web tool, a navigation bar directs them to the appropriate page.

With the aid of the navigation bar, a pupil can access the page if they want to use the super pad. Once they get onto the page, they need to upload a pdf or write anything they want in the text box present there and then they can use the features of the application that can be reflected in the information retrieved from the pdf by using a toolbox at the right side of the page. It will help them to read at ease. It is available only for readers online.

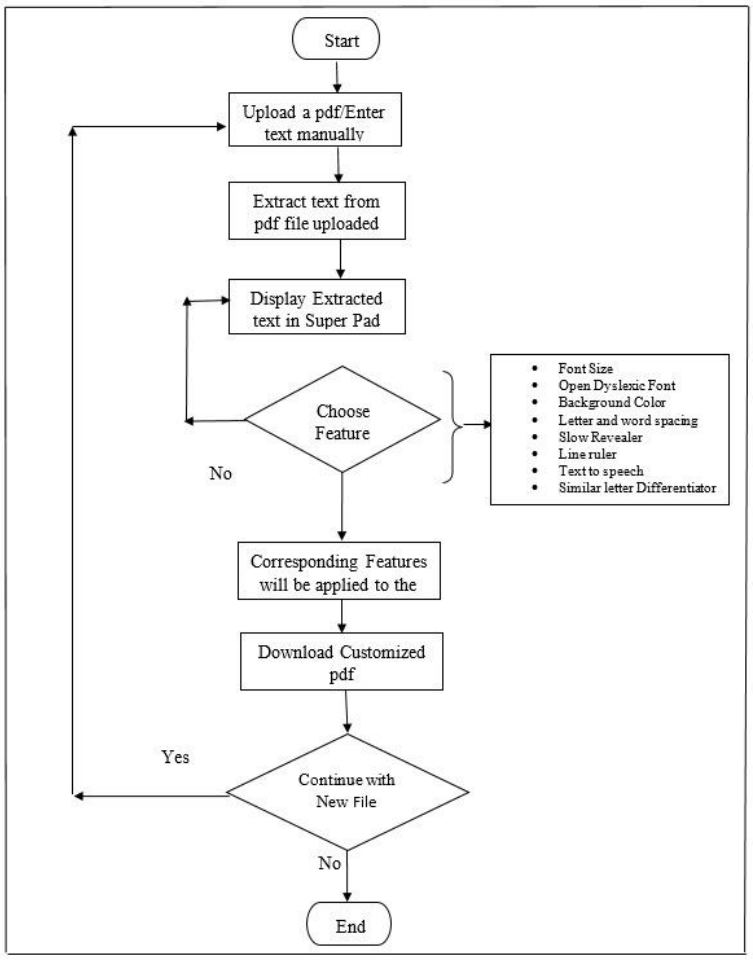

Fig. 1 Flowchart of the Super Pad Implementation

This flowchart shows a brief description of available functionalities and the flow of working in "super pad". After the usage of the functionalities, they don't have to return to the homepage because the navigation bar is available on every feature page. By using the navigation bar, they get to use the next feature. Then the people go to the next feature say, "Hydra Hunt". After entering the page, they have to their details like name and age, and select the difficulty level (Easy/Hard/Medium) and then, they will hear a storyline that will gain interest from them, so that they can understand the logic of the game and can proceed. Further, the game begins with a plot. Since this game is intended for children, we chose the adorable young girl Zaara to be its primary character. This allows the students who are playing to connect more with the character and become more engaged in the game. In the village where she lives letters are grown in trees, Zaara visits the forest every day to collect letters from the trees, string them together to form words, arrange them in a basket, and bring them back to her house so that she can sell the words for money and support her family. One fine day as she was returning

home from the forest, she tripped on a stone, breaking all of her words into letters that were then slipped into the nearby pond where each fish quickly swallowed one letter. Players should now assist her in collecting the appropriate letters by catching the fishes and forming the necessary word so that she can take them home to sell them and in turn support her family. Children with dyslexia might improve their verbal skills by playing this game. Fig. 2,3,4 depicts the flow of the functionalities. It is a word building game using a set of letters according to the audio that will be played

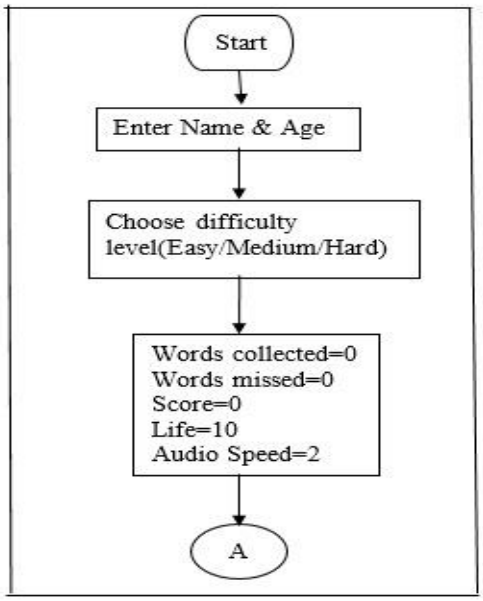

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Fig. 2 Flowchart of Hydra Hunt implementation

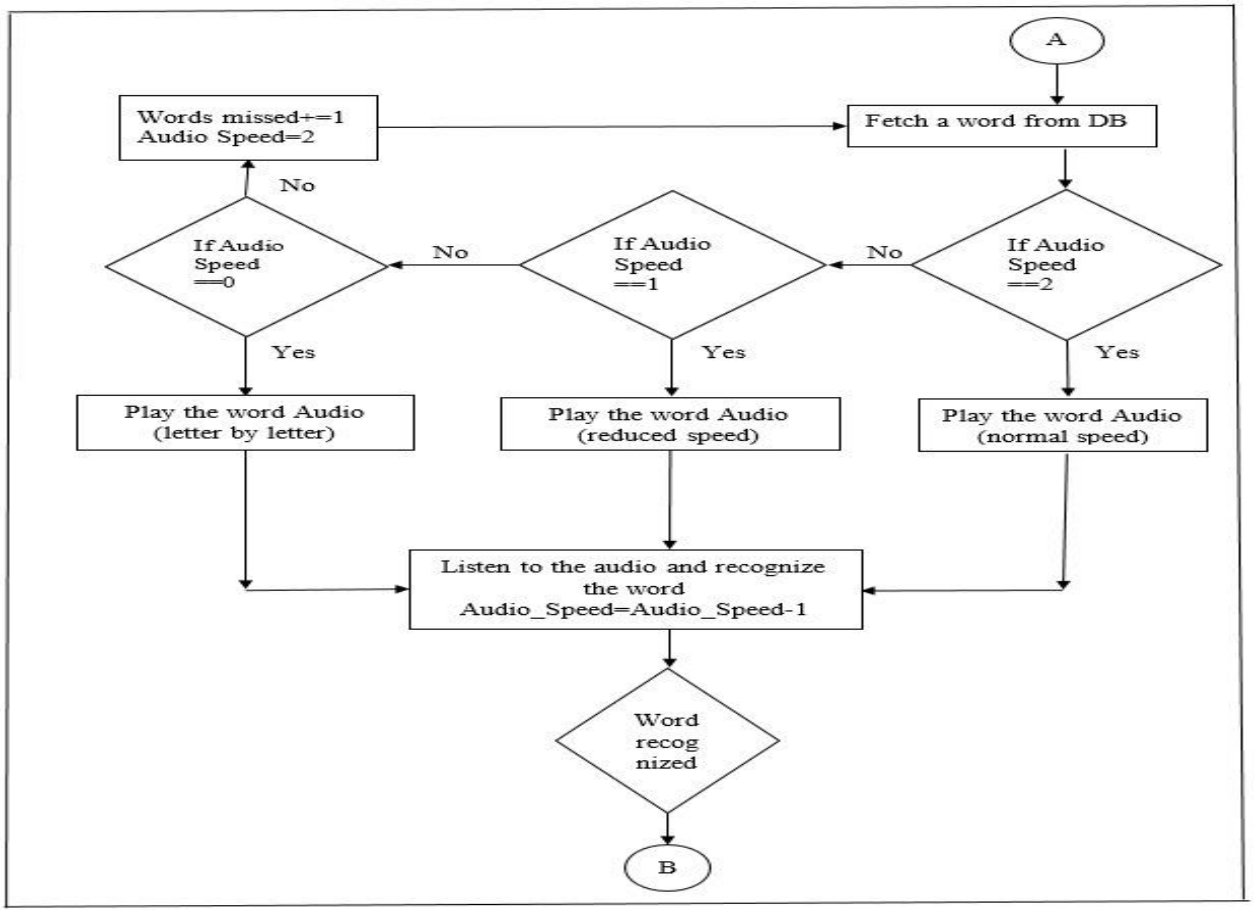


Fig. 3 Flowchart of Hydra Hunt implementation

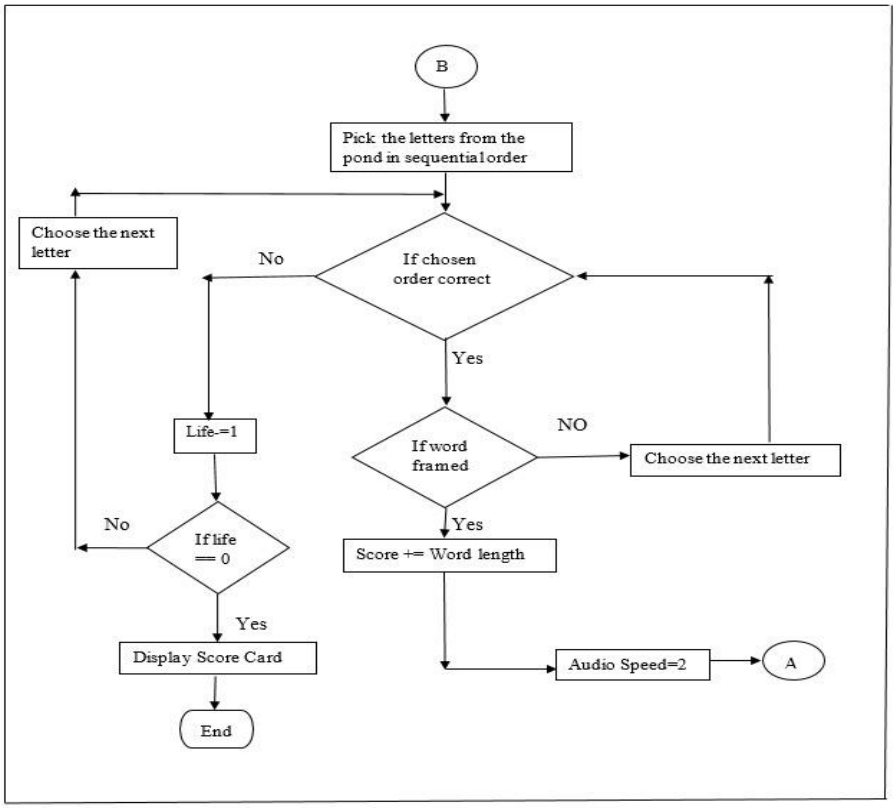


Fig.4 Flowchart of Hydra Hunt Implementation

We also have another feature Alpha 360 that be accessed through navigation bar. This page provides you with a detailed description about alpha 360, its features, and sample screenshots. This app can be easily downloaded from play store. The Quick Response (QR) code will be attached on our website Dyslexi Duo that will navigate you to the Play Store to download the app at user's convenience. Alpha 360 is a learning platform that helps dyslexics to understand alphabets, numbers, any object in real world using multisensory technique that uses more than one sense at a time here we use three senses (visual, auditory, tactile). Here are a few options and a basic search bar where we can search any object that will result in a related image in 3D with its respective audio. If we search inside the options given, then we will get an exact 3D image of the search. Although there are many learning platforms or methods for dyslexics, Alpha 360 provides you with a learning style that includes both auditory and visual in 3D where most of the providers implemented this in 2D. This makes our app unique. It provides a 360-degree immersive view which helps them to learn letters, numbers and words. Fig.5, Fig 6, Fig 7 represents the flow of functionalities.

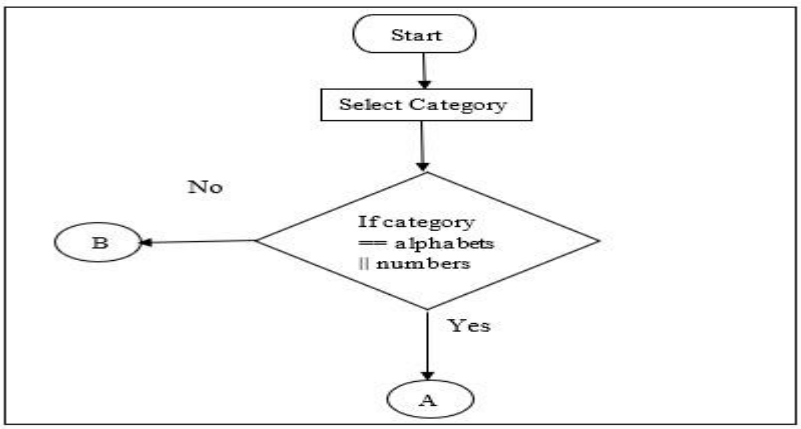


Fig.5 Flowchart of Alpha360 implementation

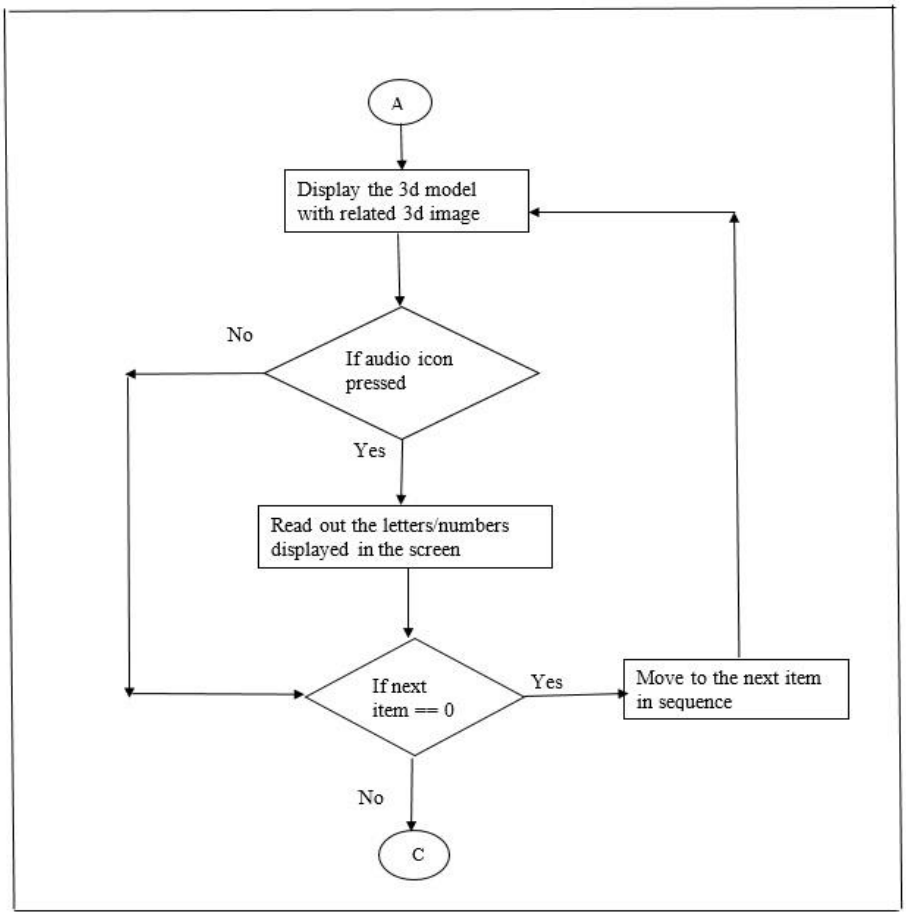


Fig.6 Flowchart of the Alpha360 Implementation

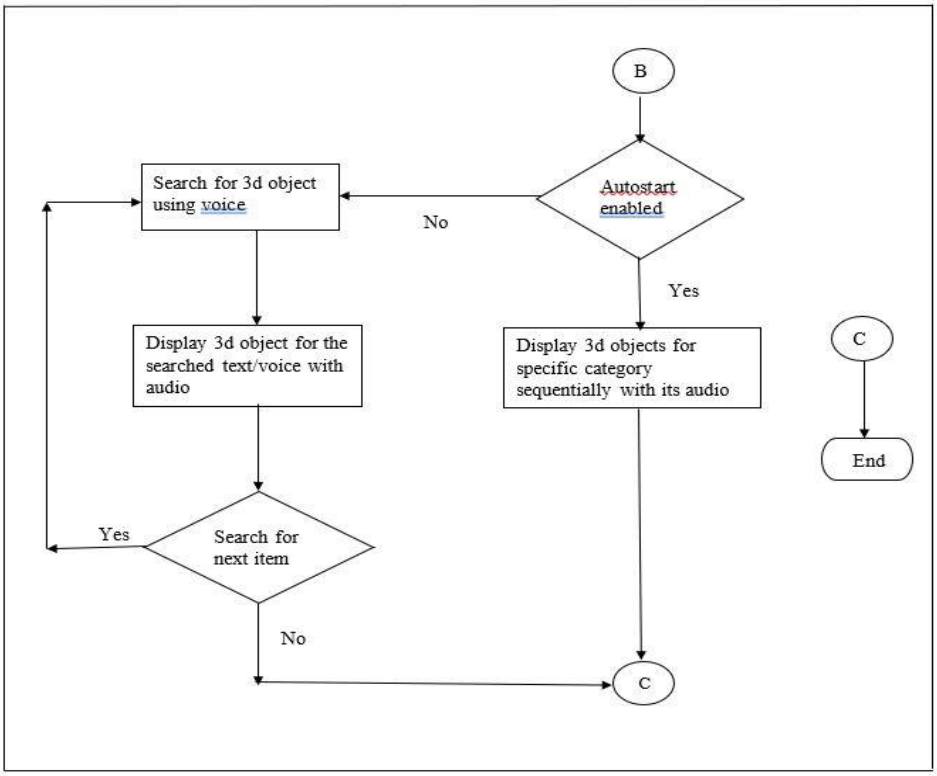


Fig.7 Flowchart of the Alpha360 Implementation

(3) Dyslexi Duo – Functions & Outcome

Dyslexic Duo is a one-point solution for dyslexic people where they can learn and make it easy to read digital documents and rehabilitate their brain through games.

Our Dyslexi Duo comprises of a Super Pad which in turn extracts words from the uploaded pdf and provides various customization features such as open dyslexic font, font size, to customize the text rendered from the pdf file. Along with that one can save changes and download the pdf for later use. Functionalities in this tool can be broadly classified into two categories, Customization & Assistive tools. Font Customization: This feature of our tool enables users to switch the document's font type to Open Dyslexic Font, which insists on special letters designed to accommodate dyslexic readers. Notably, the letters in this font have a distinct shape, with heavier bases to improve differentiation. Fig. [8] depicts this functionality. Additionally, users have the option to adjust the font size to their preferences, further enhancing the reading experience. Background Customization: This feature allows readers to customize the background color to their specific needs. In line with the recommendations of Rello L & Bigham JP (2017) warm background colors such as peach, orange, and yellow are included for use, with the options for users to choose their preferred background color. Moreover, our tool implements Light mode and Dark mode features to enhance the reading experience and make cursor tracking more manageable. By default, light mode is applied. Spacing: This feature enables the readers to increase or decrease both letter and word spacing as desired. While spacing can be increased to any extent, decreasing it is limited to the default spacing.
We also proposed some assistive tools that help dyslexic students namely, Text to Speech: By reading the full document aloud, this tool aids dyslexic readers. Readers are given the option to decrease or raise the reading pace (playback speed), and they may also select the voice in which they like to hear the text. This feature is extremely adjustable in many other ways as well. The user has access to two voices—a male voice and a female voice—that have been created to sound more human than robotic. The playing audio can be paused and resumed at any moment. Moreover, the audio can be downloaded for later use. Differentiator: Since dyslexic people have a problem understanding letters with mirror images or transpositions such as ‘b d’,‘m w’,‘h n’,‘e c’, ‘p q’. To avoid such a problem, we introduced a feature called “Differentiator". This feature helps readers by differentiating such letter pairs with standard unique colors like blue for ‘b’ and green for ‘d’.
Digital method of sweep sweep spell named Slow revealer, the letters are gently unveiled one at a time. By preventing letter & word confusion, this aids the reader and improves fluency. The reader has control over the speed at which letters are revealed. Line cursor, a digital enhancement of native technique of using a slit of paper in order to avoid confusion while reading. This cursor goes along with the reader. They can read more efficiently and stay focused on the line they are reading at any given time. Some of the functionalities might be similar to other providers but it is crucial to note that most of these providers typically concentrate on modifying web content only via a chrome Extension, and do not offer the ability to alter PDF content. Our tool stands out by providing a unique set of features which include “Slow Revealer” and “Letter Differentiator”. Moreover, our tool provides extensive customization options particularly in the domain of PDF content modification. Overall, this Super Pad demonstrates our tool's commitment to inclusivity and accessibility for individuals with dyslexia.
The proposed game of our hydra hunt acts as a web-based game that can be easily accessed by anyone and played using any web browser. This is a part of our comprehensive solution dyslexi duo. While designing this game we took several findings into consideration so that we can develop a perfect game especially for dyslexic kids. Considerations we took while designing the game are, 1. Most of the studies concluded that multisensory technique is the key for teaching dyslexics, so we were sure that our game should make use of at least more than 2 senses. And finally, we decided to use 3 senses namely- visual, auditory & kinesthetic. 2. Background colors affect the usability of our game, so we planned to stick with warm colors rather than cool colors. 3. To make this more dyslexic friendly we attached a text to speech functionality at every instruction in our game and made sure the font type is also dyslexic friendly by using Open Dyslexic font. 4. Since our target audience is small

kids, we decided to include cartoon characters and a story line to make it more interactive. The user has to give their details and will be led to hear a storyline for better understanding and grabbing attention.

After the storyline and user data process is completed, the player is sent into the game and the game starts. Fig [9] depicts user interface of the game Hydra Hunt. Player needs to click the audio button to hear for the word which Zaara needs. The first time when an audio is played, it entirely reads out the word. If the player did not catch or recognize the word, they can replay the audio but this time the audio speed will be decreased so that it reads out the word syllable by syllable. In case they still they cannot get the word, the audio will be played letter by letter. If they recognized the word correctly at any of the above three times the students must pick the letters from the pond (catch the fishes) in a sequential order one by one. If the chosen letter is correct, they can continue to choose the next letter. This process will continue until the given word is framed. Once the word is framed their score point will be equal to length of the word, and they can continue with next word. If the chosen order is incorrect their life will be decreased by one. After their life becomes zero game is over and the score card will be displayed mentioning detailed analysis of the game played.

The proposed learning tool, Alpha 360 is for kids of age group 3-8 suffering from dyslexia to learn letters by displaying alphabets and numerals in a sequential manner in 3D coupled with audio. The flow diagram present in Fig [5] depicts the proposed design of this Alpha360 in Dyslexi Duo. Once the app is downloaded to the home screen you will get the option to translate alphabets, numbers or words. Alphabets and number learnings act as a default start that is all the alphabets/numbers are displayed sequentially with the 33D representation of corresponding letters in both uppercase and lower case along with audio and related 3D object like “A for APPLE”. Fig [10] shows this functionality. In the words category we have several subcategories which include "Animals," "Fruits," "Vegetables," and "Vehicles." In this we have both default and random search. When coming to random search users can use the microphone to ask for any words under any corresponding category. Here speech to text functionality is implemented which is more beneficiary way to search particularly for dyslexic students. Once the search query has been passed a corresponding 3D object, letter, spelling and audio (playing at pace) is displayed. There is also a default search option whereby one can enter any word irrespective of category, and a 3D image and audio linked to it will be displayed.

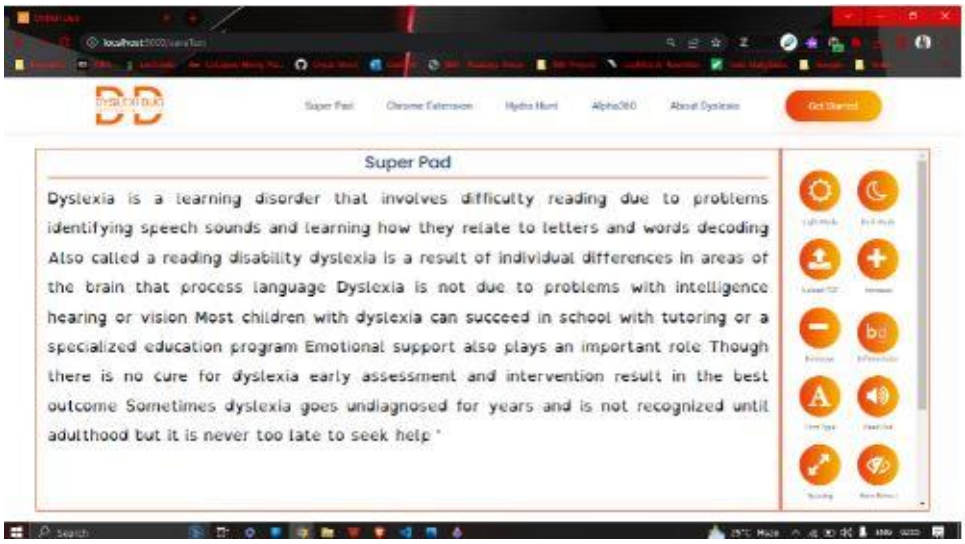


Fig. 8 Open Dyslexic font is applied to the uploaded pdf document

Fig.9 Interface of the game Hydra Hunt

Fig.10 screen showing start default of Alphabets

(4) Results & Discussion:

Based on several studies there were many methedology implemented to diagnose or to reduce the difficulty of their reading and learning capabilities. The methodolgy to aid their learning was intoduced by Ronald Davis that were done traditionally. The methodology namely sweep sweep spell, multisensory techniques that is tactic(where they used to touch and feel every letter and learn), audio-

visual technique, kinesthetic techniques. These were the methods that are followed traditionally to aid their reading and learning difficulties.

These methods were helpful while the students are learning in person with their tutor. They did improve their reading and learning skill at a minimum rate of 23% while doing these traditional methods. While testing these methods one at a time the result percentage varies depending on the student capability.

We thus conducted research with 45 individuals of various ages to evaluate our application, which digitally executed all of these conventional procedures. They watched our website with interest as we demonstrated our online tool to them.

Firstly, we gave our web tool to the age group between 11 and 17. We demoed the feature super pad and lately we made them to use. As these students were finding it difficult to read a paragraph or line in the digital document. By applying the features like font type, font size, differentiator and many more features that were mentioned above. After applying these features to the paragraph, out of 16 students 12 were able to read one or two sentences in a paragraph and tried reaching the minimum level of fluency but other students felt difficult to read as they faced difficulty in hearing the audio. Therefore, by testing this feature their accuracy and learning falls to 48%.

Person	**Age**	**Feature**	**Dyslexic People (before) (%)**	**Dyslexic people (after) (%)**
Person 1	11	Font Style	15	35
Person 2	13	Text to speech	20	45
Person 3	14	Differentiator	30	45
Person 4	16	Spacing	20	55
Person 5	17	slow reveal	30	60

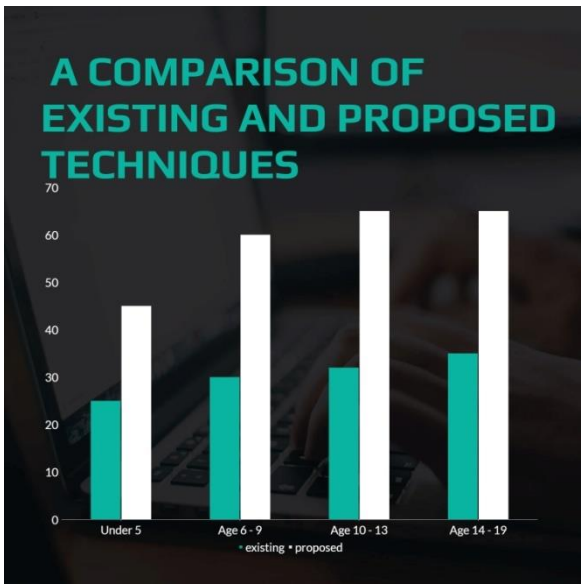
Next, we interacted and evaluated the students of the age group between 4 and 7. We made them use Hydra Hunt and they were at the level of recognizing the letters, but they struggled to read two or three letter words. So, we showed them how to use the game and they tried on their own by listening to the audio playing the word and decoded the words. Out of 14 students among the age group 11 were able to decode the words they hear. They felt it was very useful and were able to succeed in framing the words. Among the 14, three students felt it was hard to identify the letters on the fish as letters of the same color. Further, this feature met a success rate up to 51%

Age	**Weeks (%)**	**Results (%)**
3-8	1	30
	2	45
	3	58
	4	70

Then, we interacted with the students of the age group between 3 and 5. These age groups of students find it very difficult to recognize the alphabet. So, we introduced the feature Alpha360, and we guided them to use. Then we evaluated the result by testing our features. Out of 10 students among the age group 5 students found it interesting and learnt the alphabet. They were also able to learn, recognize, and see the pictures related to the letters or words. By evaluating them they were able to recognize and memorize the alphabet with the help of a three-dimensional way. Lastly, this feature that met a minimum success rate up to 65 %.

Person	**Beginning (%)**	**Syllable (%)**	**Words (%)**
Person 1	10	25	45
Person 2	20	46	68
Person 3	35	55	76

Overall testing all the features that were implemented in a digital way to aid them in reading and learning was very helpful and met a minimum success rate up to 55% to 65%. Fig 11 represents the comparison of methodologies.



- Proposed Methodology

- Existing Methodology

Fig 11. Comparison of existing and proposed methodology

(5) Conclusion:

This paper presented a comprehensive web tool to help dyslexic in every aspect to improve their knowledge irrespective of their age group. It mainly focuses on supporting dyslexic people or students to overcome obstacles they face in this digital world. These two features Super pad and Alpha360 guide them to read digital documents and learn alphabets, numbers & words in an easier manner. The goal of the web tool is to enable adults to read digital documents and children in the age group of 3 to 8 develop basic level reading and fluency. An educational game “Hydra Hunt” is also included to help them learn more effectively. Many resources are created to aid dyslexic pupils; however, they must be downloaded into their browser, which can be time-consuming and ineffective. The Super Pad, Hydra Hunt, and Alpha360 tools, which are all integrated into one area by this web applications and are seen to be highly useful. This can be used by the student to achieve their fundamental reading level and eventually achieve academic success.

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