

# A Review of the Computer Science Literature Relating to Dyslexia Diagnostic and Education

Beyza Çay, Pınar Cindemir, Mustafa Mert Aydin, Kutay Kaymakçı and Göktuğ Erdem

{c1911020, c1911018, c1911011, c1911034, c1911025}@student.cankaya.edu.tr

Department of Computer Engineering, University of Cankaya

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## Abstract

This study examines the effects, diagnosis, and treatment of dyslexia, a neurological disorder, on children. It aims to determine how to create the most beneficial educational content for children by comparing the software tools used. The study examines dyslexia in two different areas: health and software. The health side of the study is designed to observe children with this disorder better and discuss the disease's effects on children. The software side of the study examines the software used in diagnosing and treating this disorder and the projects that have been done so far. Our study will help you to understand better what dyslexia means for children, to evaluate the tasks done in this regard, and to learn about the diversity of software.

## **1. Introduction**

Dyslexia is characterized by an unexpected difficulty in reading in children and adults who otherwise possess the intelligence, motivation, and schooling considered necessary for accurate and fluent reading. Dyslexia (or specific reading disability) is the most common and most carefully studied of the learning disabilities, affecting 80 percent of all those identified as learning disabled [1]. Although the diagnosis and implications of dyslexia were once quite uncertain, recent advances in our knowledge of its epidemiology, neurobiology, and genetics, as well as of the cognitive influences on this disorder, now allow physicians to approach dyslexia within the framework of a traditional medical model. Dyslexia, which has six types (Phonological Dyslexia, Surface Dyslexia, Visual dyslexia, Primary Dyslexia, Secondary (Developmental) Dyslexia, and Trauma Dyslexia), begins to be seen chiefly in childhood.

Dyslexia is caused by impairment in the language processing center in the brain's left hemisphere. Theories put forward to suggest that an individual with dyslexia has a genetic predisposition; that is, if family members also have dyslexia, the suspicion of dyslexia increases. The standard method used in diagnostic studies of dyslexia is Electroencephalogram (EEG). There are many treatment methods for dyslexia, and a few of them are vocabulary development, word prediction, text-to-speech, and pronunciation recording. These can be treated face-to-face or with applications on smart devices.

Many applications have been developed to identify or treat dyslexia. The algorithms used in these applications are classification algorithms and kNN algorithm-like algorithms. The common language used for such algorithms is the Python programming language. Python is a programming language because it has built-in machine learning algorithms and is also open source. These applications are educational games developed to support individuals' learning processes and are designed to motivate them and attract their attention. Such applications are made considering the participation of various stakeholders such as teachers, students, psychologists, software engineers, and more. When we look at the various mobile applications designed to diagnose children with learning disabilities in the mobile

application world, the most downloaded and voted on are the Dyslexia Quiz, Reversals For Dyslexia, and Smartex. Innovative Exercises are Dyslexia AI, Auto Train Brain, Read&Write Gold, Speechify, Dyslexia Quest, Writing Wizard, and Simplex Spelling Light.

## **2. Dyslexia from a health perspective**

### **2.1. What is Dyslexia?**

Dyslexia is a neurodevelopmental condition characterized by slow and imprecise word identification. Dyslexia has been a feature of every culture study, and growing evidence suggests that its neurobiological and neurocognitive underpinnings resemble each other across languages [2].

### **2.2. What Causes Dyslexia?**

The reasons for dyslexia are not fully understood. It may be linked to genetic factors or other factors that may affect brain development. It may be related to an impairment in the brain's ability to process phonemes. It is not caused by an intellectual disability and is neurobiological in origin. It is not caused by an intellectual disability and is neurobiological in origin. Olson did not find any obvious cultural or obvious biological (ie brain-damaged) causes of dyslexic problems other than the usual genetic and environmental conditions [3].

As with all behavioral disorders, the cause of dyslexia is multifactorial and associated with multiple genes and environmental risk factors. Dyslexia is a familial disorder with moderate heritability, and replicated linkage studies have linked nine risk loci (DYY1-DYY9), although not all studies have replicated these findings. The major advance in dyslexia genetics since the last Lancet seminar was the identification of six candidate genes [4].

## **2.3. Which Types of Dyslexia Have?**

There are six different types of dyslexia. These;

1. Phonological dyslexia: People may have difficulty pronouncing some words in this type of dyslexia. Visual processing problems are more prominent than auditory problems in this type of dyslexia..
2. Surface dyslexia: This is the type of dyslexia that causes difficulty in recognising and writing out words.
3. Visual dyslexia: Difficulties in reading caused by problems with vision (due to physical causes) or problems with visual processing (due to cognitive/neurological causes).
4. Primary dyslexia: This is the most common form of dyslexia. It is a functional disorder that occurs in the left hemisphere of the brain and does not change with age.
5. Secondary (developmental) dyslexia: Secondary dyslexia is the result of problems in brain development during the early stages of fetal development. As a child grows, developmental dyslexia may improve.
6. Trauma dyslexia: This occurs in adults or children. It occurs when the brain is damaged by trauma or disease.

## **2.4. Age Groups Affected by Dyslexia**

Dyslexia is most commonly diagnosed in childhood. A significant minority of the child population is affected by this disease. Prevalence rates vary according to the criteria used to define the disease, the measures used to assess reading ability, and environmental factors. The prevalence rates of dyslexia vary between 3 % and 15 % of children of school age. Several epidemiological studies have reported that dyslexia is slightly more common in males than in females. However, a meta-review of all these studies showed that dyslexia is diagnosed more often in males than in females, and in studies of the samples cited, the ratio of males to females was up to six times higher. A higher incidence of comorbid conduct diseases, such as attention deficit hyperactivity disorder (ADHD), has often been attributed to the over-representation of males in referred samples, in males with dyslexia than in females with dyslexia. Fewer studies have investigated the prevalence of poor comprehension. However, in

unselected samples, recent studies suggest that between 7.5% and 10% of primary school children are affected by this reading disability. Unlike dyslexia, poor reading comprehension appears to affect similar numbers of males and females. Of course, dyslexia and reading disability are best thought of as extremes of the normal distribution of reading ability. They are not distinct categories, so prevalence rates are a function of the arbitrary cut-off points used to define the disorder [5].

## 2.5. Effects of Dyslexia?

Dyslexia does not have significant effects, but it does have minor effects. Even if someone with dyslexia recognises speech sounds, they may have difficulty learning their relationships to letters or words. Often seen as a reading disorder, dyslexia can also affect attention and memory, and the areas of the brain that process language.

People with dyslexia have average intelligence and usually have no problems with their vision. Most dyslexic children can do well in school with tutoring or special education programmes. Emotional support plays an important role in coping with dyslexia.

Although there is no specific treatment for dyslexia, early diagnosis and intervention give the best results. However, in some cases, dyslexia may go undiagnosed for years and not be recognised until adulthood. However, it is never too late to get help and support for dyslexia.

## 2.6. Essential Metrics of Dyslexia

The above are the total essential metrics of dyslexia

### 1. Hearing and Speech Metrics

Phonological awareness: This is the ability to recognize and manipulate the sounds in words.

Rapid naming: This is the ability to quickly name objects or symbols. People with dyslexia may be slower than average at rapid naming tasks.

Articulation: This is the ability to produce speech sounds correctly. People with dyslexia may have difficulty with articulation, which can lead to speech errors such as lisping or dropping sounds.

## **2. Vision, Reading, and Spelling metrics**

Word recognition accuracy: This is the ability to accurately identify and pronounce words. People with dyslexia may have difficulty with word recognition, which can slow reading and poor reading comprehension.

Reading fluency: This is the ability to read smoothly and effortlessly. People with dyslexia may have difficulty with reading fluency, which can make it difficult to read aloud or to read for extended periods of time.

## **3. Writing and speed ability metrics**

Writing speed: This is the rate at which a person can write legibly. People with dyslexia may have difficulty with writing speed, which can make it difficult to complete writing tasks in a timely manner.

## **4. Arithmetic and time managing metrics**

Number sense: This is the ability to understand and manipulate numbers. People with dyslexia may have difficulty with number sense, which can lead to problems with arithmetic and mathematics.

Time management: This is the ability to plan and organize one's time effectively. People with dyslexia may have difficulty with time management, which can make it difficult to complete tasks on time.

## **5. Memory and cognition metrics**

Short-term memory: This is the ability to hold information in one's mind for a short period of time. People with dyslexia may have difficulty with short-term memory, which can make it difficult to remember instructions or to follow a multi-step process.

Working memory: This is the ability to hold information in one's mind while simultaneously performing other tasks. People with dyslexia may have difficulty with working memory, which can make it difficult to follow directions or to learn new information.

Processing speed: This is the speed at which a person can process information. People with dyslexia may have slower processing speed than average, which can make it difficult to keep up with classroom instruction or to complete tasks quickly.

## 6. Behavior, health, development ,and personality Metrics

Self-esteem: People with dyslexia may have low self-esteem due to their struggles with reading and writing.

Anxiety: People with dyslexia may experience anxiety related to schoolwork or social situations.

Motivation: People with dyslexia may have difficulty staying motivated in school due to their learning challenges.

Social skills: People with dyslexia may have difficulty with social skills due to their struggles with reading and communication.

## 7. General characteristic metrics

Intelligence: People with dyslexia are typically of average or above average intelligence.

Creativity: People with dyslexia may have strengths in creativity and problem-solving.

Resilience: People with dyslexia often develop resilience and perseverance due to their challenges.

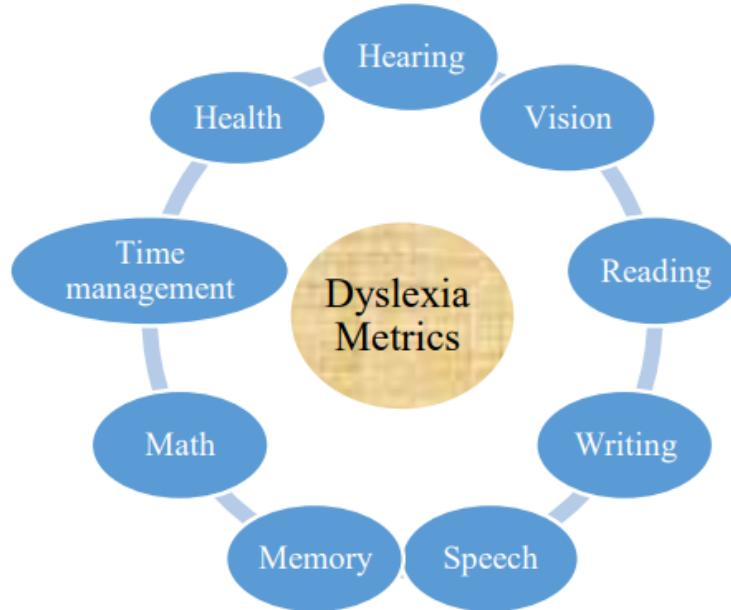


Figure 1. Dyslexia metrics [6],

## 3. Diagnosis of Dyslexia from a health perspective

Firstly, to summarize, Dyslexia is a condition that makes it hard for people to read and understand written words. It affects how quickly and accurately they can decode letters into

sounds and words. People who are dyslexic may have difficulty decoding speech, recognising and manipulating basic language sounds, retaining language and learning letter sounds.

Dyslexia is a brain disorder caused by genetics. People with dyslexia have abnormalities in their brains. The brain is split into two sections: the left part deals with language and numbers, while the right part handles spatial reasoning [7]. Dyslexia is caused by damage to the left side of the brain's language center, which results in difficulties with reading, writing and spelling [8].

A dyslexic person has differences in how the brain works and how electrical activity works. Many current ideas look for what causes dyslexia in biology, especially in genes that might make someone more likely to develop it. Some variations in the way the brains of individuals with dyslexia and those without learning difficulties function and their anatomical structures have been noted.

Every individual (child or adult) who doubts subjects such as reading, math problems, and focusing should receive an assessment. This assessment is usually carried out in schools, higher education institutions, and psychological counseling. The evaluation should include a comprehensive measurement of reading, spelling, and arithmetic skills. As recent research in the field has shown, an intelligence test or IQ score is not required.

The diagnosis of dyslexia is made by evaluating the child's reading, writing, and pronunciation skills. A speech and language therapist or a special education teacher usually makes the diagnosis. There are several criteria for the diagnosis of dyslexia:

- Assessment of potential familial problems, intelligence level, language ability, word
- Recognition, speaking
- Assessment of language skills
- Recognise and understand words.
- Assessment of speech and reading language skills
- Reading Literacy
- Vocabulary assessment
- Assessing the ability to understand and read new and unfamiliar words.
- To assess the functioning of a person's brain in terms of phonology (pronunciation).

Diagnosis can be facilitated by comparing the results with the survey and test results. If family members also have dyslexia, the suspicion of dyslexia increases. At the same time, because the indicators used to diagnose developmental dyslexia involve a range of language challenges — i.e., accuracy in word recognition and difficulties in fluent speech, poor spelling, and solving abilities — the main focus of research into the pathophysiology of the disorder is on the impact of the language processes. The best known theories about the workings of auditory speech are:

1. The theory of phonological deficit explores difficulties in processing speech sounds, including their storage, manipulation, and reception.
2. The dual difficulty theory, which explores difficulties in both sounding out words and naming objects quickly.

### **3.1. Electroencephalogram (EEG)**

Electroencephalogram (EEG) can detect dyslexia by describing the electrical signals in the brain. These signals are collected through metal electrodes placed on the scalp. EEG measurements can be compared with other techniques like functional magnetic resonance imaging (fMRI) [9]. EEG is a safe and easy-to-use test. The test produces a signal that can be sorted into five categories:

- delta ( $\delta$ )
- theta ( $\theta$ )
- alpha ( $\alpha$ )
- beta ( $\beta$ ) and
- gamma ( $\gamma$ ) bands.

The frequency range bands are displayed in Table 1. Currently, in the field of neuroscience and cognitive studies, EEG is widely used as the most effective aid to diagnose, assist in analysis, observation, and comprehension of the human brain's internal processes.

Table 1. EEG Bands and Description

Bands Type	Frequency Ranges	Bands Description
Delta ( $\delta$ )	0-4 Hz	This individuality can be detected during periods of deep sleep.
Theta ( $\theta$ )	5-7 Hz	It is improved by sleep mode
Alpha ( $\alpha$ )	8-13 Hz	Occurs when you feel restless, relaxed or mentally inactive.
Beta ( $\beta$ )	14-30 Hz	It is noticeable when the mind is attentive
Gamma ( $\gamma$ )	36-40 Hz	The original text lacks context and already adheres to the given principles of simple writing, complex tasks.

## 4. Treatment of Dyslexia from a health perspective

In treating Dyslexia, it is necessary to identify the disorder at the very beginning, determine the symptoms of the child's symptoms, and take a path according to the signs. The treatment to be performed depends on the severity of Dyslexia and psychological symptoms or simultaneous disorders. Drug therapy is not helpful for Dyslexia. But if a dyslexic patient has attention deficit hyperactivity disorder (ADHD), medication for ADHD can also improve their ability to learn inside and outside of school.

### 4.1. Dyslexia treatment methods

The model for Dyslexia includes two causal and two symptomatic levels that overlap over time. Certain techniques and approaches employed to manage Dyslexia comprise:

#### 4.1.1. To propagate reading features

- Change the temperature and color of the text
- Adjust line spacing
- Place highlights and text components

- Text-to-speech reading
- Word guess
- Vocabulary development

#### **4.1.2. To propagate writing features**

- Spell check and grammar check
- Word guess
- Vocabulary development
- Writing style improvement

#### **4.1.3. To improve pronunciation skills**

- Read aloud
- Pronunciation record
- Feedback

### **4.2. Other Methods that Are Effective in the Treatment of Dyslexia**

#### **4.2.1. The Orton-Gillingham Method in the Treatment of dyslexia**

Samuel Ortan realized in his study that neurological problems that exist in people cause people to confuse letters and create reading problems [10]. Deciphering reading, writing, and speaking as language teaching, Orton has designed an instructional method to establish a connection between symbols and sounds used in colloquial language [11]. In this method, visual, auditory, and dynamic stimuli are put to work simultaneously. In addition to voicing and visually presenting words in teaching, analyzing each sound contained in the phrase individually tracking the spelling directions of letters with fingers can be expressed as one of the program's main features.

In the method, the students first create sound awareness, and each sound contained in the word is analyzed individually. Then, vowel and consonant letters are put to work, and new comments are taught to students. After this stage, syllabic studies are performed, and the writing stage can be started. The points that should be focused on in teaching are instant and abundant feedback, reading speed, and the realization of good reading.

The Orton-Gillingham Method Example:

1. Assume the child wants to be taught the letter 'm'. The letter M is written on the card, and the sound of the letter is made.
2. He then asks the child to make the sound of the letter after going over the letter. It is done again until the child learns the symbol and sound of the letter.
3. After this stage, the child writes the letter in the air and on paper, saying the sound of the letter as they write.
4. Once the child has learned several letters, they are asked to write out deciphered words one letter at a time.
5. Then, words are formed with mixed letters. This step is repeated by forming words with different letters.
6. The printed words are taught to the student by spelling.
7. The words in the book, determined under the teacher's guidance, are read to the student.

#### **4.2.2. The Fernald Method in the Treatment of dyslexia**

The development of this method by Grace Maxwell Fernald, is a method for children with dyslexic and excessive reading difficulties, where visual, auditory, mobile, and tactile senses are put to work, which differs from other multisensory methods in terms of teaching words as a whole [12]. The Fernald method, which is incredibly successful by students over the age of 8, helps the child recognize the letters and words necessary for learning to perform reading activities, as well as helps to eliminate inversion errors and symbol confusion during reading over time [13]. This method can be applied in developing reading and writing activities and other courses where students' interest is concentrated [14].

The Fernald Method consists of 4 steps:

1. The word the child chooses is written on paper using a colored pencil. While reading the word, the child is made to follow the talk with his finger by touching the paper. Then, he is asked to write the comment in his notebook by looking at the word written on paper. The process starts again if the child makes a mistake while watching or writing the

word. The situation that should be noted is that the word is always written as a whole.

2. The child reads by looking at the handwritten word and writes from his mind without looking at the word. Correctly spelled words are put into the file alphabetically according to their initials. If he makes a mistake in spelling the word, the first step is repeated. Adding comments to the file continues until a story is created from words. After these operations, the child makes a story with the words he adds to the file and writes the story.
3. In this step, the child has reached the level of learning the words that have been written. For this reason, the process of writing sample words in handwriting is abandoned. The child reads the words he wants to learn by looking at the letters, and then learns by writing. Now he can perform the activity of reading from a book. When there is a word that the child cannot read, it can be helped.
4. In this last step, the child looks at the printed words, repeats them, and can write the comment without looking at the word. He can learn new words from similar terms. The student has now reached a level where he can develop himself.

#### **4.2.3. The Warnke Method in the Treatment of Dyslexia**

Recognising the signs of developmental dyslexia has been the main focus of clinical research. The analysis of patient data has helped improve the diagnosis of specific learning problems. This has resulted in the creation of a dependable diagnostic method and useful tools [15]. Creating a comprehensive system to aid and examine kids with developmental Dyslexia has become a significant focus [16].

The technique intends to improve the processing of auditory and visual signals in the central nervous system. It focuses on training the coordination of auditory-motor timing, maintaining balance automatically, and reacting to sound stimuli. These skills are crucial for reading and writing.

### **4.3. The Brain-Boy Universal Professional (BUMP) Device**

Brain-Boy Universal Professional (BUMP) is a tool for testing and improving a child's hearing and vision. It offers activities that children can complete wearing headphones. Based on the findings from the initial assessment, we propose developing a tailored programme to meet the child's individual needs and abilities.

The Brain-Boy Universal device is primarily used to enhance skills. The usage plan is determined by the BUP device's evaluation results, which rank the number of games played per session and the level of difficulty. The device features eight games and enables the adjustment of difficulty based on the user's performance.

Central auditory and visual processing can be evaluated through Warnke's method tasks that need specific equipment, like headphones [17]:

1. The Visual Brain-Boy game
2. The Auditory Brain-Boy
3. The Klik-Boy game
4. The Sound-Boy game
5. The Sync-Boy
6. The Speed-Boy
7. The Trio-Boy
8. The Long-Boy game

## **5. Algorithms and techniques used in diagnostic applications in dyslexia**

Many computer applications have been developed to diagnose dyslexia, which has dramatically helped diagnose this disease.

### **5.1. Dyslexia Diagnosis and Classification System**

Research has been done in Malaysia, A nation that is relatively young with a population of 31.66 million in 2016. 4-10% of students have been found to have signs and symptoms of dyslexia. The University of Malaysia has developed a

machine-learning classification algorithm that helps diagnose dyslexia at an early age. They compiled data from 857 primary school students [18].

### **5.1.1. The Algorithm**

The classification algorithm analyzes the input data and generates an output. As a supervised task, classification needs a predefined target for each sample. The aim is for the algorithm to learn enough to be able to predict and score as closely as possible.

kNN (K Nearest Neighbors Classifier) algorithm was chosen for its better accuracy for this particular data, and supervised learning was used. kNN classifier is best suited for binary classification [19].

There are three categories of machine learning for classification:

- Statistical pattern and recognition [20]
- Machine learning techniques for induction of decision trees or production rules [21][22]
- Connectionist [23]

Python programming language is selected as a tool since it has built-in machine learning algorithms and is open source.

Scikit-learn provides algorithms for machine learning tasks, including classification, regression, dimensionality reduction, and clustering [18]. It also includes modules for feature extraction, data processing and model evaluation. The user interface of the system is designed using the TKinter graphical user interface in Python.

## **5.2. Mobile Application to Support Dyslexia Diagnostic and Reading Practice**

The main objective of this thesis is to present an application developed to provide dyslexic users with reading exercises to improve their diction of words in the Portuguese language and, on another hand, as a tool to support health professionals in diagnosing potential cases of dyslexia. Therefore, it can check whether the user's reading follows a predefined set of disadvantages that dyslexics commonly face when

reading Portuguese. The verification of the developed tool regards its assertiveness, sound interference, and use with dyslexic people [24].

This application can randomly generate one word at a time for the user to read. The application verifies if the word spoken corresponds to the word presented. A new word is given after five trials if the response is the opposite.



Figure 2. Speaking exercise pages of the application.

The application was developed using a prototyping-based methodology, within which each step was reviewed and incremented. It was initially designed for Android mobile devices, using Android SDK (Software Development Kit), Java, and applying the Nuance voice recognition tool Dragon Mobile SDK (Software Development Kit).

### **5.3. New Method to Diagnosis of Dyslexia Using 1D-CNN (1 Dimensional Convolution Neural Network)**

Electrooculogram (EOG) is one of the methods used to detect eye movements. This study proposed a new method for diagnosing dyslexia. EOG signals were recorded while healthy and dyslexic individuals were reading four different texts prepared in the same font and four different font sizes. Recorded EOG signals were classified using a 1D Convolutional Neural Network for classification [25].

## **6. Software Applications For Dyslexia Treatment**

In the world of mobile applications, developers design various mobile apps to diagnose learning difficulties in children. Furthermore, technological solutions such as mobile devices and artificial intelligence-based assistants have garnered significant interest in addressing these children's educational and learning needs. This review focuses on using artificial intelligence to diagnose individuals with dyslexia, enabling their educational progress through interactive games that cater to their specific needs and the design principles of applications specially crafted for children.

A study of 114 children aged 4 to 7 years provided evidence that children can learn from mobile apps. However, to maintain their interest, these apps should be developed with fresh content, reduced wait times, engaging activities, incentives, goals and parental involvement [26].

### **6.1. Machine Learning for the Identification of Dyslexic Individuals**

Cognifit developed games for testing dyslexic individuals, as shown in [27, Figure 3] and [28, Figure 4]. Children's accuracy is determined based on their in-game actions. Additionally, these games aim to enhance the areas where children may have deficiencies.

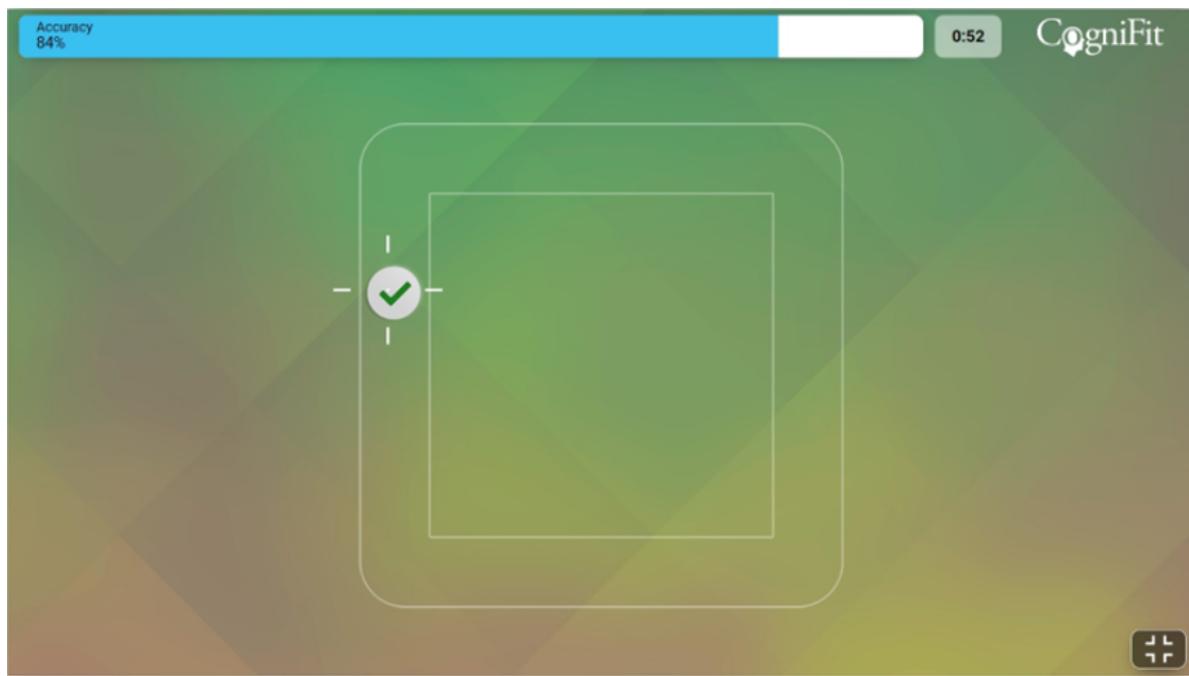


Figure 3. Eye-Hand Coordination Test example with accuracy measured

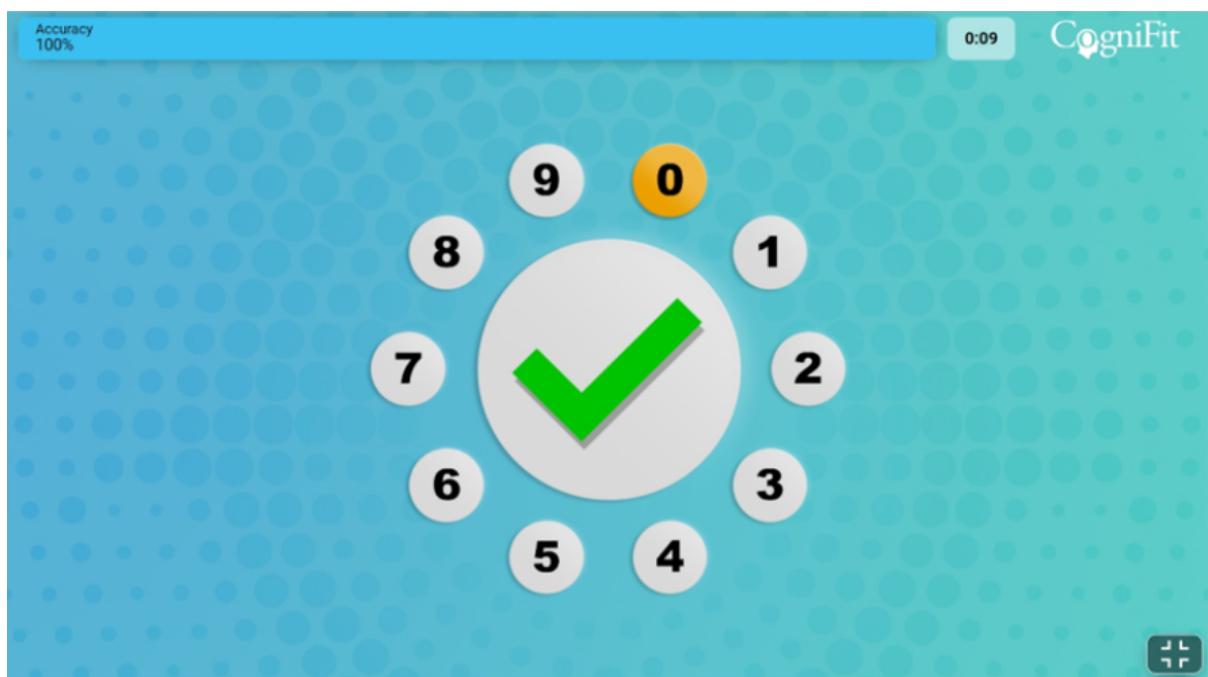


Figure 4. Digit span test example with accuracy measured

## **6.2. Educational Games for Dyslexic Individuals**

Developers design educational games to support the learning processes of dyslexic individuals, aiming to motivate and capture their attention. These games, in particular, should possess the ability to provide customized content for children's education and make the learning process enjoyable. To address the learning needs of dyslexic children, we recommend proposing a software development process model as a solution for creating educational applications. Such models should embrace a user-centered approach, considering the involvement of various stakeholders like teachers, students, psychologists, software engineers, and more [29]. Research indicates that developing educational applications requires different perspectives from stakeholders such as teachers, psychologists, programmers, students, and IT analysts. [30]. Thus, it is crucial to have a software engineering process that integrates analysis, design, development, evaluation, and more.

## **6.3. Artificial Intelligence-Based Assistants**

Artificial intelligence-based assistants aim to provide personalized learning experiences for dyslexic students. These assistants utilize various data sources to determine strategies and tools tailored to the needs and learning styles of dyslexic students. Student surveys, clinical analyses, and other data sources are fundamental in operating artificial intelligence modules. These studies aim to assess the performance and effectiveness of AI-based assistants.

According to a project, artificial intelligence and virtual reality were used to identify the challenges faced by dyslexic students. In preparation for this project, a comprehensive dataset was collected and preprocessed. The first experiment to demonstrate the performance of the proposed artificial intelligence tool used a dataset obtained from Italian universities. This dataset consists of responses from 719 dyslexic students to 52 questions. Among these questions, 12 address various problems caused by dyslexia (comprehension difficulties, writing challenges, concentration issues), 17 investigate the usefulness of specific learning support tools (concept maps, differently colored words), and the remaining 22 explore different

learning strategies and activities for students. The answers to these questions were collected and analyzed using a Likert scale. We evaluated various algorithms such as Random Forest (RF), k-nearest Neighbors (kNN), Support Vector Machines (SVM), and Logistic Regression to determine the best model and configuration for predicting each tool and strategy from this dataset.

When examining the results presented in Table 2 [31, Table 2], we can observe that the top three models with the best performance are SVM Linear with a score of 0.9761, SVM RBF with a score of 0.9633, and kNN with a score of 0.9538 when K=7. On the other hand, the model with the lowest score is again SVM RBF with a score of 0.7246. When evaluating the results, it is evident that the same models yield different scores. As a result, factors such as the threshold value, input type, and data consistency may contribute to different predictions from the same model (SVM RBF). Further analysis is required to determine the precise factors influencing the best results.

Table 2. Best Model to Predict each Support Tool

<b>ID</b>	<b>Best Model</b>	<b>Thr</b>	<b>Input</b>	<b>Cons</b>	<b>Score</b>
T1	SVM RBF	4	Numeric	Yes	0.7443
T2	RF, 50 estimators	4	Numeric	No	0.9433
T3	SVM Linear	1	Binary	No	0.9111
T5	SVM RBF	1	Binary	Yes	0.8852
T6	KNN K=7	1	Binary	No	0.9538
T7	SVM Linear	1	Binary	No	0.9761
T8	KNN K=11	1	Numeric	No	0.9325
T9	SVM RBF	1	Binary	No	0.9298
T10	SVM RBF	1	Binary	No	0.9436
T11	SVM RBF	4	Binary	Yes	0.7246
T12	SVM RBF	4	Binary	Yes	0.7410
T13	KNN K=9	1	Binary	No	0.9449
T14	SVM RBF	1	Binary	Yes	0.9633
T15	SVM Linear	1	Binary	No	0.9354
T16	RF 50 estimators	1	Numeric	No	0.9279
T17	SVM linear	1	Binary	No	0.9367

## **6.4. Design of Customized Educational Applications**

The design of customized educational applications for children facing learning difficulties like dyslexia demands a user-centered approach. People should understand that the level of interest does not solely revolve around entertainment and games; instead, it should be based on the learning perspective in interactive educational aesthetics tailored to a specific age group. Such an environment aims to capture children's attention towards the design of cognitive applications based on their abilities, needs, and learning ease [32]. Application design should align with the age and skills of children and the objectives of the application. User-centered design, especially regarding the user interface design for any cognitive application targeting disabled children, is a fundamental aspect of Human-Computer Interaction (HCI) [33]. The application interface should be user-friendly, focusing on user satisfaction and ease of use.

Research has shown that there are various multimedia cognitive learning applications previously designed. [34, Table 3] presents the main components, frameworks, and algorithms used in these applications for dyslexic children. This table lists the components used in various applications [35].

Table 3.Components used in various applications

<b>Application Name</b>	<b>Features</b>
Dyslexia Baca	Developed in Malaya language, assist alphabet recognition, motivated then to learn and read, repetitive activities of game, reward pages and based of ADDIE model.
MyLexic	Developed in Malaya language, dual coding theory and scaffolding instructional technique has been used and courseware prototype is used
EasyLexia 1.0	Content, activities, course, motivation, word finder games, choose it game, sound finder game, text legible, avoid background stimuli, achievements.
Improve Writing with mobile Application for dyslexia	A mobile app, Writers Learning Algorithm (WLA), text legible, significant multimedia elements, avoid background stimuli. User profile, the progress of the user.

According to research, applications emphasize content and educational software over user interface design. If the flow of the designed application is user-friendly and motivates the user to interact with the system enjoyably for cognitive learning, learning outcomes can be improved [36].

## 6.5. Example of Applications

### 6.5.1. Dyslexia Quiz

The software application facilitates a comprehensive understanding of the impact of dyslexia on children aged 5-11 in an engaging manner. It proves exceptionally advantageous for parents and educators seeking insights into the experiences of children with dyslexia. The 4-minute test incorporated within the application encompasses 50 potential symptoms of dyslexia. The application effectively illustrates the ramifications of dyslexia on a child's performance in reading, writing, memory tests, and planning. These activities

help children discover how many symptoms of dyslexia they have. [37, Figure 5] displays the interfaces of the Dyslexia Quiz application.



Figure 5.a. Introduction and reading exercise page of the application



Figure 5.b. The writing and memory exercise page of the application

Figure 5. 'Dyslexia Quiz' application interfaces

#### 6.5.2. Reversals For Dyslexia

It is an application that includes activities based on preventing confusion of letters such as b-d, p-d-b, and numbers 6-9, which are common symptoms of dyslexia, and reducing these problems. Within the application, users can choose between letters or numbers and engage in activities where they can flip them vertically or horizontally. [38, Figure 6] displays the interfaces of the Reversals For Dyslexia application.

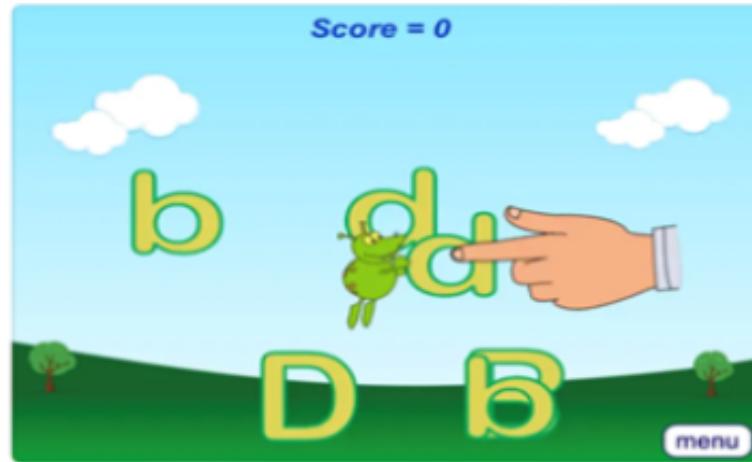


Figure 6.a. Game example of the application

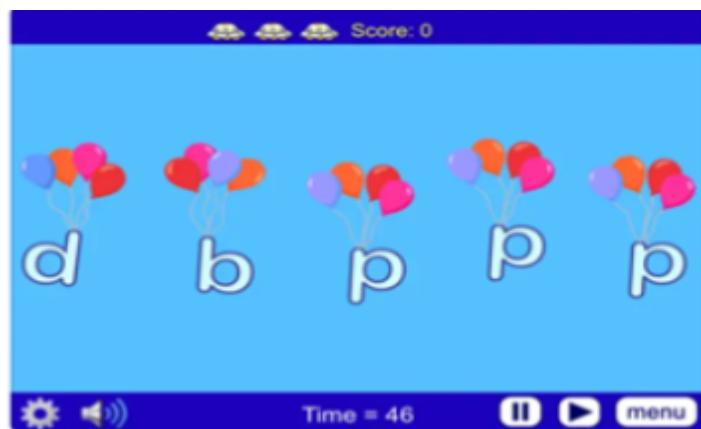


Figure 6.b. Game example of the application

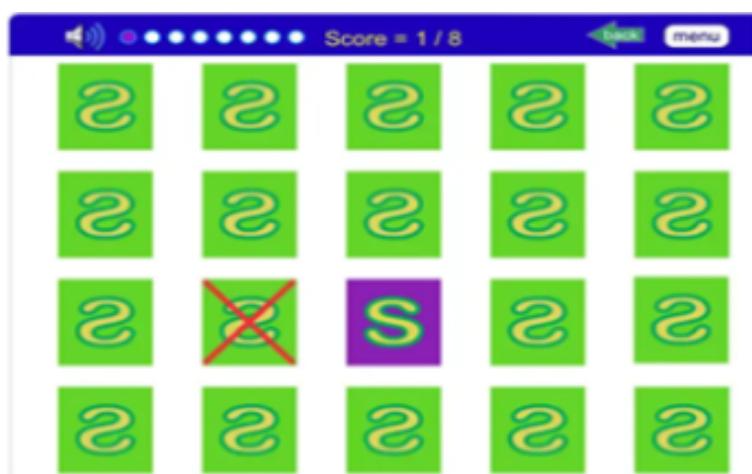


Figure 6.c. Game example of the application

Figure 6. Reversals For Dyslexia application interfaces

### 6.5.3. Smartex Akıllı Alıştırmalıklar (EN: Smartex Smart Exercises)

Developers created the application to address neurological issues such as dyslexia, dysgraphia, dyscalculia, and speech-language disorders. It incorporates activities such as letter matching, picture matching, word puzzles, and auditory puzzles, allowing users to listen, comprehend, and match. The application aims to address the challenges faced by children with this type of neurological disease through games, which are tailored based on the child's performance. The application is ad-free and free. Gains provided by the application:

- Development of Phonological Awareness Skills
- Development of Attention and Focus Skills
- Development of Visual Perception Skills
- Development of Reading and Writing Skills
- Development of Auditory Perception Skills
- Development of Optical Discrimination Skills
- Development of Mathematics Skills
- Development of Articulation Skills
- Development of Language and Speech Skills
- Development of Memory Skills

Smartex Smart Exercises application interfaces are given [39, Figure 7].



Figure 7.a. Smartex Application Main Page

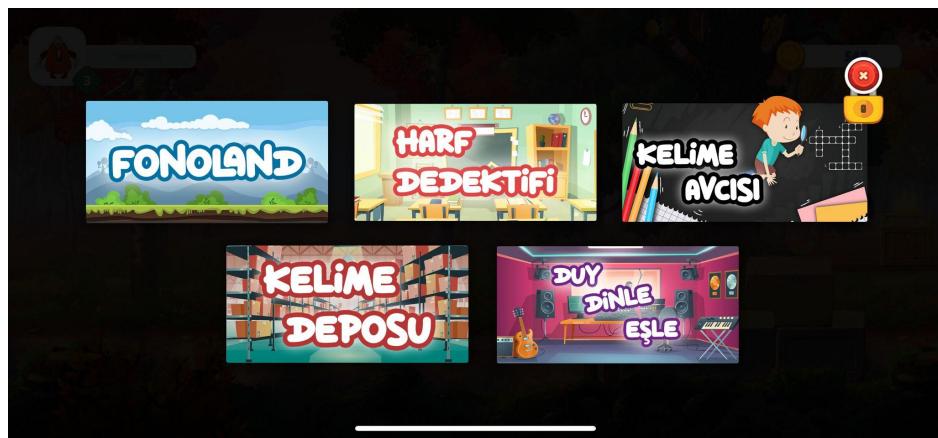


Figure 7.b. Game in dyslexia (TR:Disleksi) part of application

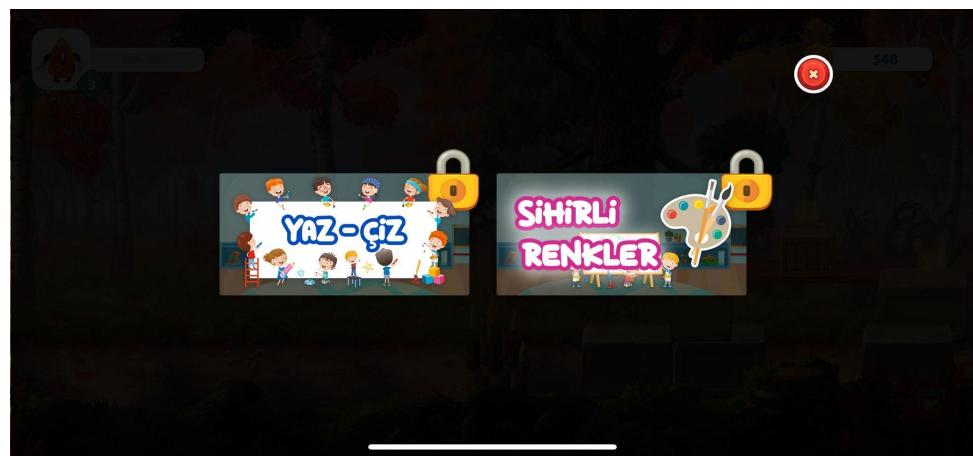


Figure 7.c. The games in the dysgraphia(TR:Disgrafi) part of the application



Figure 7.d. The games in the dyscalculia(TR:Diskalkulija) part of the application

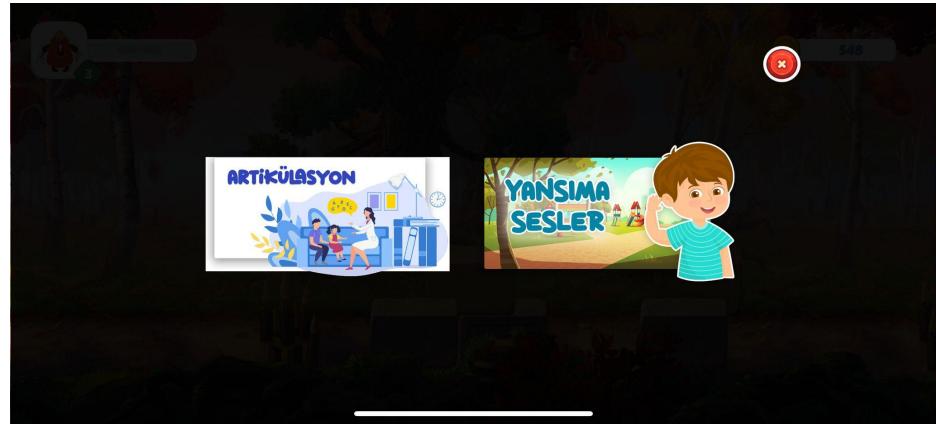


Figure 7.e. The games in the dyscalculia(TR:Diskalkulia) part of the application

Figure 7. Smartex Smart Exercises application interfaces

#### 6.5.4. Dyslexia AI

The application's design aims to enhance the reading and spelling skills of children with dyslexia. The application puts children to the test with unique games. These games include features such as categorizing words according to their phonetics, making sounds of words, and artificial intelligence-supported voice recognition, and the rewards won from the game are displayed with augmented reality. [40, Figure 8] illustrates the interfaces of the Dyslexia AI application.

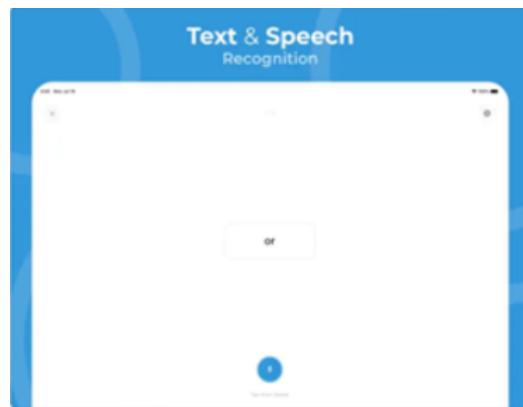


Figure 8.a. Text & Speech part of the application

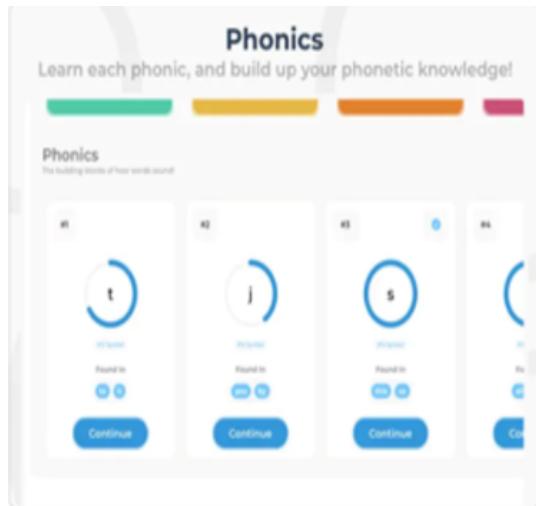


Figure 8.b. Phonics part of the application

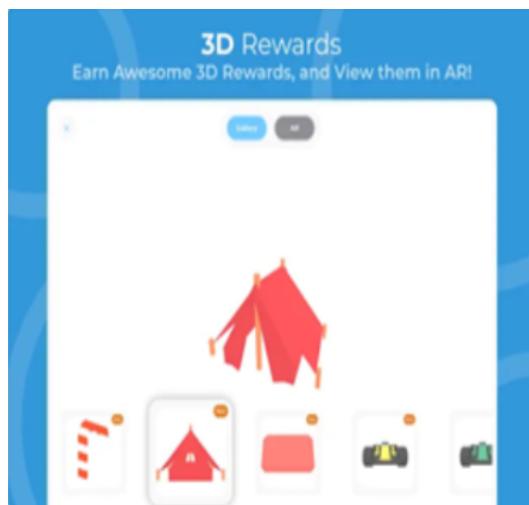


Figure 8.c. 3D Rewards part of the application

Figure 8. Dyslexia AI application interfaces

#### 6.5.5. Auto Train Brain

The first software was the dyslexia application called AutoTrainBrain, developed by Günet Eroğlu, a PhD student at Sabancı University. Believers argue that using this software increases children's reading speed and reduces the likelihood of errors. AutoTrainBrain completed the testing process with 100 individuals and received support from TÜBİTAK. The statement mentions that the annual subscription fee is \$250. [41, Figure 9] displays the Auto Train Brain application interfaces.

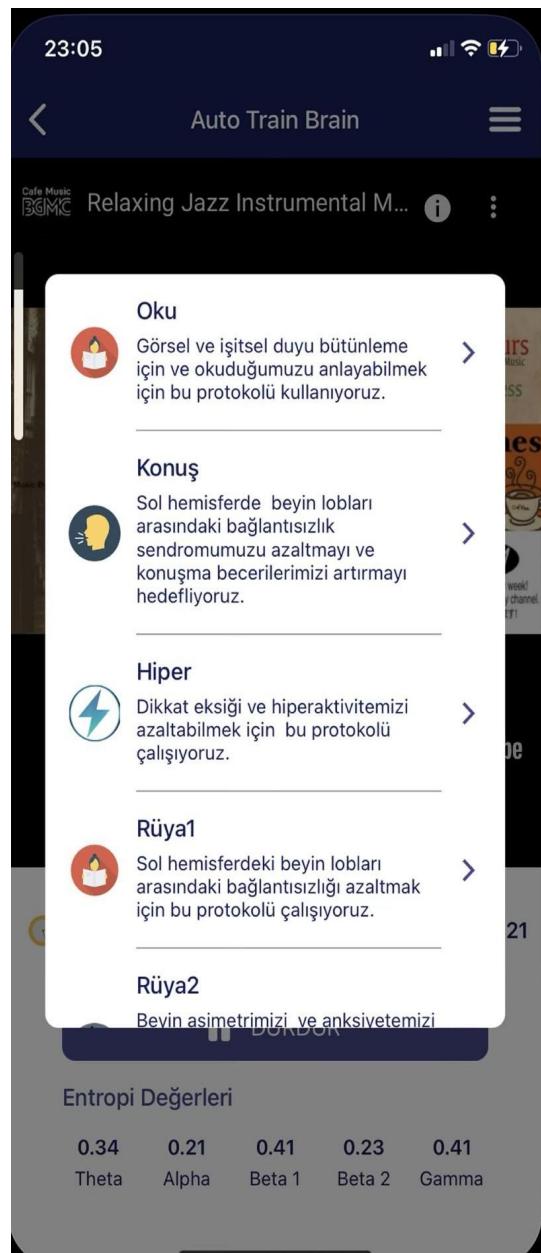


Figure 9.a. Information protocols used in the application

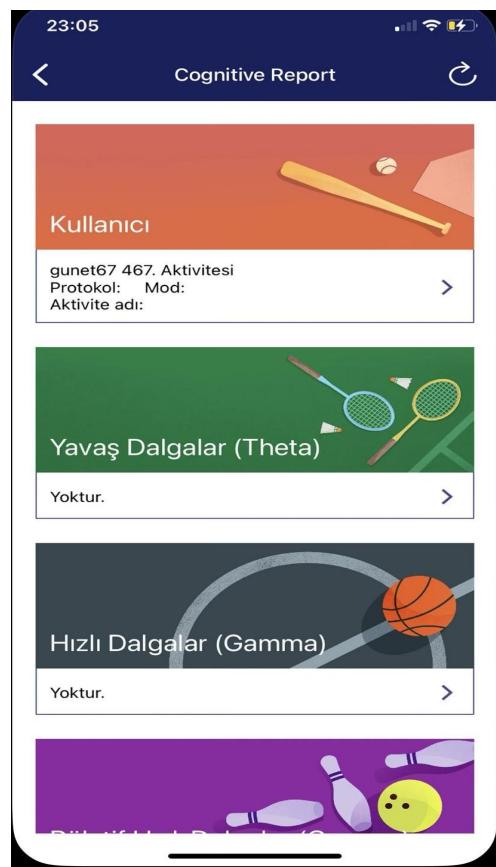


Figure 9.b. Application Cognitive report section

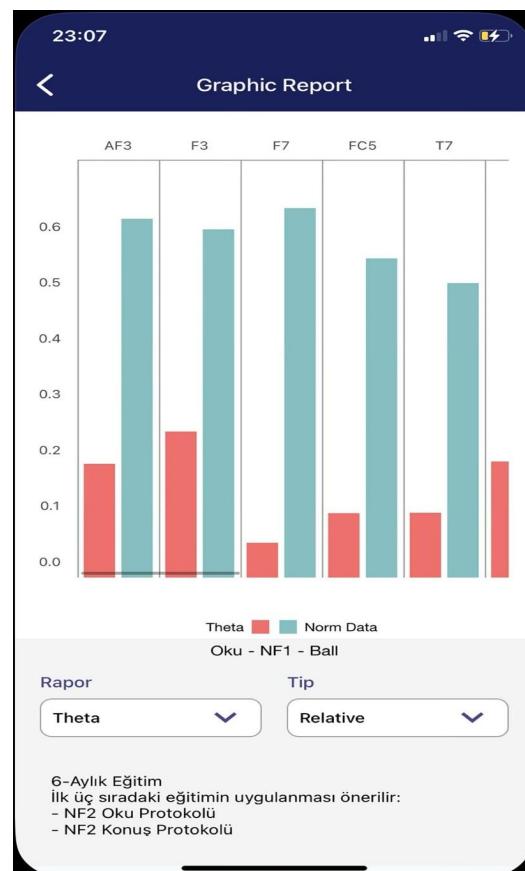


Figure 9.c. Application Graphic report section

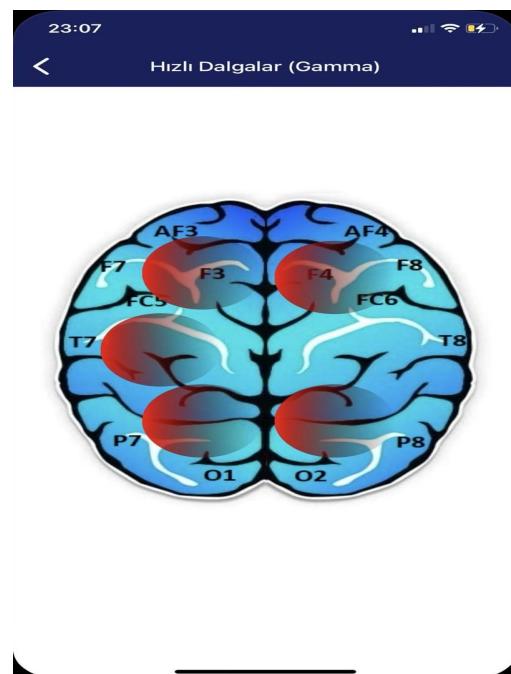


Figure 9.d. The results of the tests performed show in the brain

Figure 9. Auto Train Brain application interfaces

### 6.5.6. Read&Write Gold

Texthelp developed Read&Write Gold, an easy-to-use software that users can access from a computer or phone. It attempts to alleviate dyslexia and other learning disabilities by reading text typed on the screen or any text aloud. It increases the individual's self-confidence by reading bold or double-colored areas aloud with the add-ons available in the application. If we count the features it includes, these are Listening to Speech by Reading Text, Guessing/Filling in Words, and Translating Words. It is a type of software that is easy to install and start using. [42, Figure 10] illustrates the interfaces of the Read&Write Gold application.

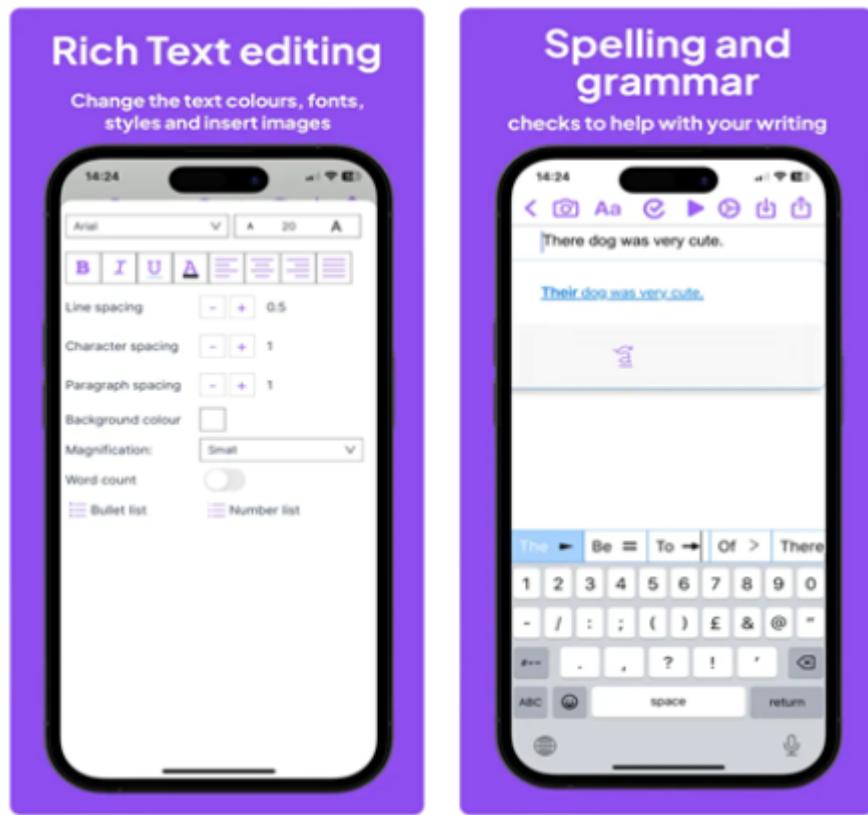


Figure 10.a. Rich text editing Spelling & Grammar Part of Application

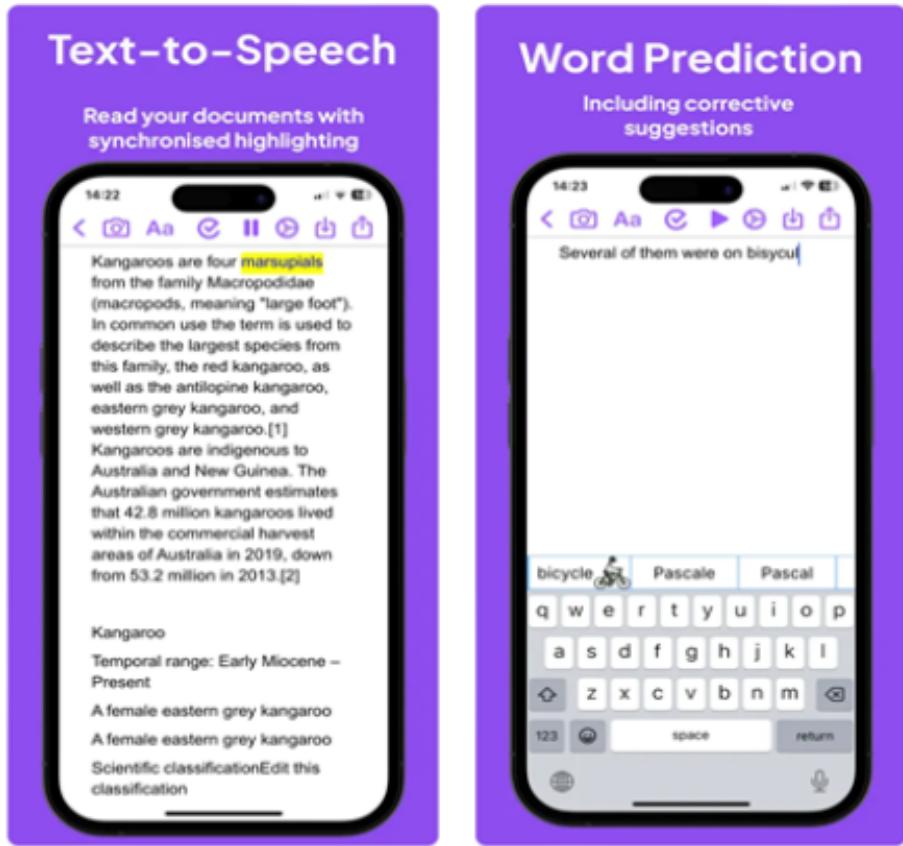


Figure 10.b. Speech-to-Text & Word Prediction Part of Application Figure 10. Read&Write Gold application interfaces

#### 6.5.7. Speechify

It is a software application that can help people with dyslexia and others with ADHD, autism, and other learning disabilities. Through the translation of text into speech and the highlighting of text, the application enhances the perception of letter sounds. It promotes focused attention on words, thereby facilitating improved fluent reading. The incorporated software enables enhanced text comprehension, fostering an increased interest in reading. This software application, compatible with most browsers, is accessible and usable at no cost. [43, Figure 11] displays the interfaces of the Speechify application.

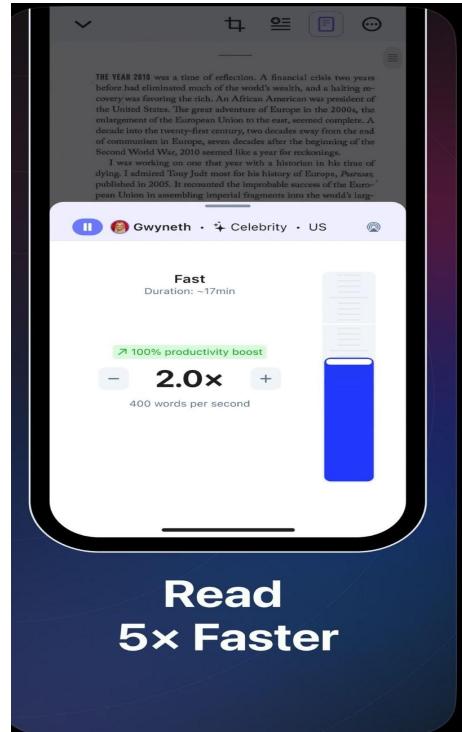


Figure 11.a. The effectiveness of measuring and improving the reading speed of the application

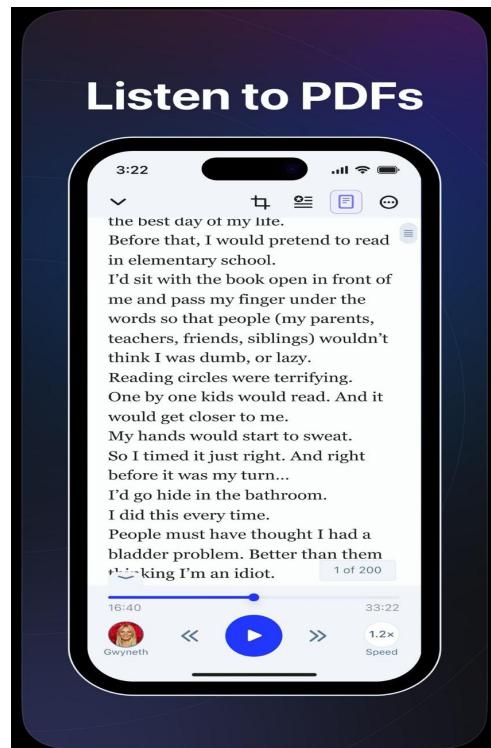


Figure 11.b. Listening and reading exercise

Figure 11. Speechify application interfaces

### 6.5.8. Dyslexia Quest

This application, which targets children between the ages of 5-11, helps overcome dyslexia with game-based tests. Developed at the Bristol Dyslexia Center, the software is accessible via the browser without downloading. Under adult supervision, it completes a game called Elimination Yeti Mountain within 20 minutes, without children realizing they are in a test, thus determining whether the child is at risk of dyslexia. In [44, Figure 12], the Dyslexia Quest application displays its interfaces.

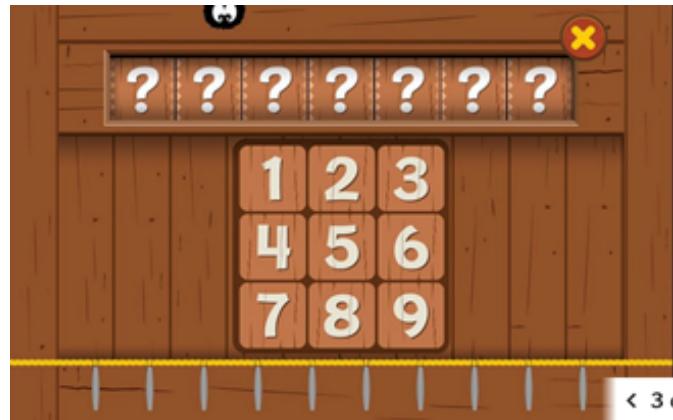


Figure 12.a. Application number sorting game



Figure 12.b Application character matching game

Figure 12. Dyslexia Quest application interfaces

### 6.5.9. Yazı Sihirbazı (EN: The Writing Wizard)

The software application facilitates writing style editing and enhances writing speed by passing over letters, words, or sentences with one's finger. This application is free for download on Google Play for ages 5-11. [45, Figure 13] illustrates the interfaces of the Yazı Sihirbazı application.

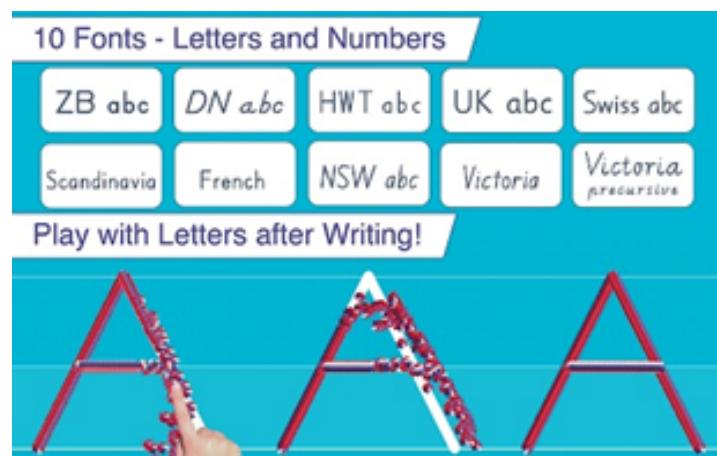


Figure 13.a Matching activity by typing numbers and letters

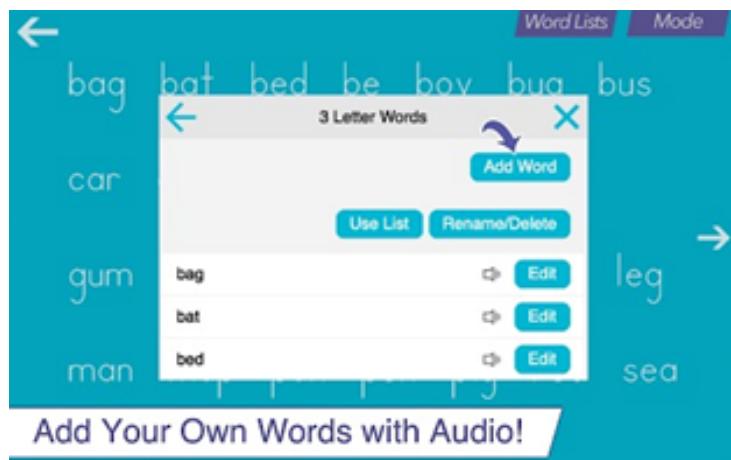


Figure 13.b Finding the right word according to the number of letters of the word

Figure 13. Yazı Sihirbazı application interfaces

### 6.5.10. Simplex Spelling Light

Designed to enhance writing and reading skills in a fun and interactive way, it utilizes 'Reverse Phonics'. The prevention of word memorization in

over 1000 languages, coupled with the facilitation of fluent speech through spelling and repetition with provided clues, comprises vital features of this application. A success message is displayed upon the correct pronunciation of a word, encouraging users to attempt to find the correct word with hints. This software application, exclusively available on IOS, is downloadable and usable at \$4.99. [46, Figure 14] displays the interfaces of the Simplex Spelling Light application.

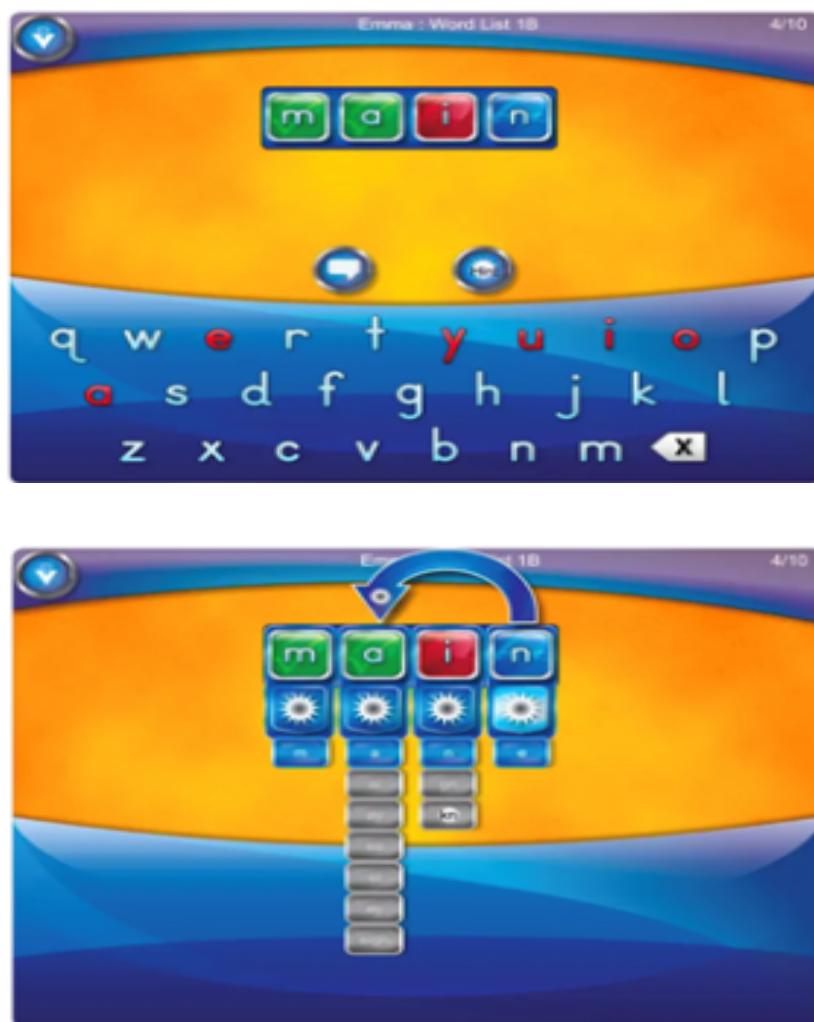


Figure 14. Simplex Spelling Light application interfaces

## **7. Conclusion**

The study examined the effects of dyslexia on children in general and the diagnosis and treatment of dyslexia. Researchers have examined which software tools are typically used to diagnose and treat dyslexia. The study describes the diagnostic and treatment aspects of dyslexia in two different areas: health and software. Researchers examined the methods used to diagnose and treat children with dyslexia and standard techniques. Researchers examined the software used to diagnose and treat dyslexia and the projects that have been developed to date. Researchers have conducted many studies on dyslexia in children. These reviews have helped us learn more about the disorder in both software and healthcare, and our work has helped you better understand what dyslexia means.

## References

- [1] Shaywitz, S. E. (1998). Dyslexia. *New England Journal of Medicine*, 338(5), 307–312.  
doi:10.1056/nejm199801293380507
- [2] The Lancet, Volume 379, Issue 9830, 26 May–1 June 2012, Pages 1997-2007  
Robin L Peterson PhD, Bruce F Pennington PhD
- [3] Research in Developmental Disabilities , Volume 134, March 2023, 104424  
Ali Fahad Aldakhil , Mona Tawakkul Ebrahim , Hesham Fathy Gadelrab.
- [4] The Lancet, Volume 379, Issue 9830, 26 May–1 June 2012, Pages 1997-2007  
Robin L Peterson PhD, Bruce F Pennington PhD.
- [5] Sheryl M Handler, in Taylor and Hoyt's Pediatric Ophthalmology and Strabismus (Fifth Edition), 2017
- [6] Research in Developmental Disabilities , Volume 55, August 2016, Pages 88-99, Yujun Ma, Enguo Wang, Tian yuan, Guo xiang Zhao
- [7] Fadzal C., Mansor W., Lee K., Mohamad S., Amrin S., Frequency Analysis of EEG Signal Generated from Dyslexic Children, 2012 International Symposium on Computer Applications and Industrial Electronics (ISCAIE 2012), December 3-4, Kota Kinabalu Malaysia.
- [8] Ministry of Education. "Literature Review: An International Perspective on Dyslexia," New Zealand Government, 2007.  
<http://literacyonline.tki.org.nz/content/download/25955/276950/file/An+International+Perspective+on+Dyslexia.pdf> (Accessed in April 2016).
- [9] Karim I., Abdul W., Kamaruddin N., "Classification of Dyslexic and Normal Children during resting condition using KDE and MLP", IEEE 5 th International Conference on Information and Communication Technology for the Muslim World, ICT4M 2013, DOI: 10.1109/ICT4M.2013.6518886.
- [10] Ritchey, K. D., & Goeke, J. L. (2006). Orton-Gillingham-Based reading instruction: A review of literature. *Journal of Special Education*. 40(3), 171-183.
- [11] Post, Y. (2003). Reflections. Teaching the secondary language functions of writing, spelling, and reading. *Annals of Dyslexia*, 53, 128-148.
- [12] Yılmaz, M. (2022). Okuma güçlüğü ve tedavisi. Ankara: Gece Akademi Yayınları
- [13] Yangın, S., & Sidekli, S. (2006). Okuma Güçlüğü Yaşayan Öğrencilerden Kelime Tanıma Becerilerinin Geliştirilmesine Yönelik Bir Uygulama. Muğla Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Muğla.

- [14] Tunç, İ. (2018). Fernald teknüğine uyarlanmış metinlerin dördüncü sınıf öğrencilerinin dinlediğini anlama becerilerine etkisi (Yüksek lisan tezi), Ömer Halisdemir Üniversitesi Eğitim Bilimleri Enstitüsü, Niğde.
- [15] Bogdanowicz, Kalka, Karpińska, Sajewicz-Radtke, & Radtke, 2012; Fawcett, Singleton, & Peer, 1998; Feifer, 2015; Flanagan, Ortiz, & Alfonso, 2013; Hook, Macaruso, & Jones, 2001; Jaworowska, Matczak, & Stańczak, 2010; Krasowicz-Kupis, 2009; Nayton, Hettrich, Samar, & Wilkinson, 2017; Nicolson & Fawcett, 1997; Reynolds & Caravolas, 2016; Wagner, Torgesen, Rashotte, & Pearson, 2013; Wiederhold & Bryant, 2012; Wolf & Denckla, 2005)
- [16] Lipowska, M., Łada, A., Pawlicka, P., & Jurek, P. (2019). The use of the Warnke Method in dyslexia therapy for children. *Journal of Applied Developmental Psychology*, 64, 101060. <https://doi.org/10.1016/j.appdev.2019.101060>
- [17] Lipowska, M., Łada, A., Pawlicka, P., & Jurek, P. (2019). The use of the Warnke Method in dyslexia therapy for children. *Journal of Applied Developmental Psychology*, 64, 101060. <https://doi.org/10.1016/j.appdev.2019.101060>
- [18] Ullah, K. R., Lee, J. a. C., & Oon, Y. B. (2018). Machine Learning and Dyslexia-Diagnostic and Classification System (DCS) for Kids with Learning Disabilities. <https://ir.unimas.my/id/eprint/21523/>
- [19] Strasburger, H., Rentschler, I., & Jüttner, M. (2011). Peripheral vision and pattern recognition: A review. *Journal of Vision*, 11(5), 13. <https://doi.org/10.1167/11.5.13>
- [20] Quinlan, J.R., Induction of decision trees. *Machine learning*, 1986. 1(1): p. 81-106.
- [21] Quinlan, J.R., C4. 5: programs for machine learning. 2014: Elsevier.
- [22] McClelland, J.L. and D.E. Rumelhart, Explorations in parallel distributed processing: A handbook of models, programs, and exercises. 1989: MIT press.
- [23] V. F. Martins, T. Lima, P. N. M. Sampaio and M. de Paiva, "Mobile application to support dyslexia diagnostic and reading practice," 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA), Agadir, Morocco, 2016, pp. 1-6, doi: 10.1109/AICCSA.2016.7945710.
- [24] Banerjee, Anwesha, et al. "Eye movement sequence analysis using electrooculogram to assist autistic children." *Biomedical Signal Processing and Control* 14 (2014): 134-140.
- [25] New Method to Diagnosis of Dyslexia Using 1D-CNN.
- [26] S. M. Daud and H. Abas, "'Dyslexia Baca' Mobile App -- The Learning Ecosystem for Dyslexic Children," 2013 International Conference on Advanced Computer Science

Applications and Technologies, Kuching, Malaysia, 2013, pp. 412-416, doi: 10.1109/ACSAT.2013.87.

[27] "CogniFit," CogniFit Brain Fitness - Try it now! Available: [https://www.cognifit.com/aplicaciones/html5/public/assessment/ASSESSMENT~@~THE\\_NUMBERS?testButtonUrl=https://www.cognifit.com%2Fbattery-of-tests%2Fwom-asm-test%2Fsequential-test%3Freg%3Dtrue](https://www.cognifit.com/aplicaciones/html5/public/assessment/ASSESSMENT~@~THE_NUMBERS?testButtonUrl=https://www.cognifit.com%2Fbattery-of-tests%2Fwom-asm-test%2Fsequential-test%3Freg%3Dtrue) (accessed Nov. 08, 2023).

[28]: "CogniFit," CogniFit Brain Fitness - Try it now! Available: [https://www.cognifit.com/aplicaciones/html5/public/assessment/ASSESSMENT~@~THE\\_MOVING\\_SQUARE?testButtonUrl=https://www.cognifit.com%2Fbattery-of-tests%2Fupda-shift-test%2Fsynchronization-test%3Freg%3Dtrue](https://www.cognifit.com/aplicaciones/html5/public/assessment/ASSESSMENT~@~THE_MOVING_SQUARE?testButtonUrl=https://www.cognifit.com%2Fbattery-of-tests%2Fupda-shift-test%2Fsynchronization-test%3Freg%3Dtrue) (accessed Nov. 08, 2023).

[29] J. M. Arteaga and D. I. Pinedo Rivera, "A Process Model to Develop Educational Applications for Children with Dyslexia," 2018 6th International Conference in Software Engineering Research and Innovation (CONISOFT), San Luis Potosi, Mexico, 2018, pp. 79-87, doi: 10.1109/CONISOFT.2018.8645896.

[30] J. M. Arteaga and D. I. Pinedo Rivera, "A Process Model to Develop Educational Applications for Children with Dyslexia," 2018 6th International Conference in Software Engineering Research and Innovation (CONISOFT), San Luis Potosi, Mexico, 2018, pp. 79-87, doi: 10.1109/CONISOFT.2018.8645896.

[31] E. Yeguas-Bolívar, J. M. Alcalde-Llergo, P. Aparicio-Martínez, J. Taborri, A. Zingoni and S. Pinzi, "Determining the Difficulties of Students With Dyslexia via Virtual Reality and Artificial Intelligence: An Exploratory Analysis," 2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE), Rome, Italy, 2022, pp. 585-590, doi: 10.1109/MetroXRAINE54828.2022.9967589.

[32] N. Shabbir, Z. Bhatti and D. N. Hakro, "Serious Game User Interface Design Rules for dyslexic children," 2019 13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS), Karachi, Pakistan, 2019, pp. 1-6, doi: 10.1109/MACS48846.2019.9024786.

[33] N. Shabbir, Z. Bhatti and D. N. Hakro, "Serious Game User Interface Design Rules for dyslexic children," 2019 13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS), Karachi, Pakistan, 2019, pp. 1-6, doi: 10.1109/MACS48846.2019.9024786.

[34] N. Shabbir, Z. Bhatti and D. N. Hakro, "Serious Game User Interface Design Rules for dyslexic children," 2019 13th International Conference on Mathematics, Actuarial Science,

Computer Science and Statistics (MACS), Karachi, Pakistan, 2019, pp. 1-6, doi: 10.1109/MACS48846.2019.9024786.

[35] N. Shabbir, Z. Bhatti and D. N. Hakro, "Serious Game User Interface Design Rules for dyslexic children," 2019 13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS), Karachi, Pakistan, 2019, pp. 1-6, doi: 10.1109/MACS48846.2019.9024786.

[36] N. Shabbir, Z. Bhatti and D. N. Hakro, "Serious Game User Interface Design Rules for dyslexic children," 2019 13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS), Karachi, Pakistan, 2019, pp. 1-6, doi: 10.1109/MACS48846.2019.9024786.

[37] "Dyslexia Quiz," App Store, Nov. 17, 2020. [Online]. Available: <https://apps.apple.com/ru/app/dyslexia-quiz/id1520570331?l=en-GB> (accessed Nov. 08, 2023).

[38] "Reversals for Dyslexia," App Store, Jun. 12, 2020. [Online]. Available: <https://apps.apple.com/tr/app/reversals-for-dyslexia/id1123467459?l=tr> (accessed Nov. 08, 2023).

[39] "Smartex Akıllı Alıştırmalar," App Store, Aug. 27, 2023. [Online]. Available: <https://apps.apple.com/tr/app/smartex-ak%C4%B1ll%C4%B1-al%C4%B1%C4%B1%C5%9Ft%C4%B1rmalar/id1673181321?l=tr> (accessed Nov. 05, 2023).

[40] "Dyslexia.ai - Smart Phonics," App Store, Feb. 25, 2023. [Online]. Available: <https://apps.apple.com/tr/app/dyslexia-ai-smart-phonics/id1564885095?l=tr?l=tr> (accessed Nov. 08, 2023).

[41] "Auto Train Brain," App Store, Jul. 18, 2023. [Online]. Available: <https://apps.apple.com/tr/app/auto-train-brain/id1591731934> (accessed Nov. 08, 2023).

[42] "Read&Write," App Store, Oct. 16, 2023. [Online]. Available: <https://apps.apple.com/us/app/read-write/id934749270> (accessed Nov. 05, 2023).

[43] "Speechify Text to Speech Audio," App Store, Oct. 30, 2023. [Online]. Available: <https://apps.apple.com/us/app/speechify-text-to-speech-audio/id1209815023> (accessed Nov. 05, 2023).

[44] "Dyslexia Quest," [www.nessy.com](http://www.nessy.com). Available: <https://www.nessy.com/en-us/product/dyslexia-quest-home> (accessed Nov. 05, 2023).

[45] "Yazı Sihirbazı - Google Play'de Uygulamalar," [play.google.com](https://play.google.com). Available: <https://play.google.com/store/apps/details?id=com.lescapadou.tracing&hl=tr&gl=US> (accessed Nov. 05, 2023).

[46] “Simplex Spelling Light,” App Store, Oct. 11, 2019. [Online]. Available: <https://apps.apple.com/us/app/simplex-spelling-light/id465715154> (accessed Nov. 05, 2023).