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# Leveraging Assistive Technology in Language Learning: The Effectiveness of Text-to-Speech (TTS) on improving Phonemic Awareness and Orthographic Knowledge of Dyslexic Children

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**Abstract:**

Rapid technological advancements are occurring in today's world. This is especially accurate when it comes to instructional multimedia. An increasingly crucial part of instructional multimedia design is the determination of the narrating voice. However, research in this field is outdated and lacks breadth. This study investigates the possibilities of utilizing assistive technology in language acquisition, specifically examining the efficacy of Text-to-Speech (TTS) technology in improving certain linguistic abilities in individuals with dyslexia. Specifically, it examines the effects of TTS on phonemic awareness and orthographic knowledge among individuals with dyslexia. The study utilizes a quasi-experimental methodology, where participants are randomly assigned to either an experimental group that uses TTS (Text-to-Speech) tools or a control group that receives traditional language training. The intervention takes place over a period of 10 weeks, in which participants interact with TTS-assisted learning modules specifically created to improve phonemic awareness and orthographic understanding. The phonemic awareness test and orthographic knowledge test were used to quantify modifications in specific linguistic abilities. Results imply a statistically significant enhancement in both phonemic awareness and orthographic knowledge among the experimental group, indicating that TTS technology is a useful tool for tackling the core difficulties associated with dyslexia. This study adds to the expanding corpus of work on assistive technology in education, providing insights into the distinct

benefits of Text-to-Speech (TTS) in tackling language-related challenges linked to dyslexia. The findings of this study have broader implications, highlighting the importance of personalized and technology-integrated methods for language learning in individuals with dyslexia. Additional investigation is necessary to examine the enduring and extended consequences of TTS interventions and to improve teaching approaches for the most favorable learning results.

**Keywords**:

Text-to-Speech (TTS) - Phonemic Awareness - Orthographic Knowledge - Dyslexics

## Introduction:

Reading and writing are important skills for getting involved in society. They are basic skills that allow individuals to communicate, share their thoughts and ideas, and understand information Reading and writing also give individuals the tools they need to take part in political discussions, get an education, find work, and engage with diverse perspectives (Hessler, 2001). A significant percentage, approximately 20%, of students come upon challenges related to reading, encompassing about 5-8% of the world's population who are diagnosed with dyslexia (Svensson, et al., 2021). The existence of these difficulties in reading can have a significant impact on individuals' ability to pursue professional opportunities. It is crucial for educational institutions and local communities to provide appropriate support and interventions to help these individuals overcome their challenges and thrive in society.

The rapid improvement of technology has made it easier for individuals to access diverse information and enhance human productivity in various domains. The Covid-19 pandemic has led to a surge in technology usage, particularly in sectors like TV and film streaming services, internet ecommerce, and mobile phones. Computer-assisted teaching and learning systems have focused on communication training, leading to more people practicing their skills. This is because people recognize the importance of clear communication in work and personal situations. These systems provide interactive tasks and real-life situations to improve spoken and written communication, making it easier for people to improve their communication skills. (Khasawneh, 2021; Hardach, 2021)

As a result, Assistive technology which includes Text-to-Speech (TTS, hereafter) and Speech Recognition Technology (SRT, hereafter) technology are becoming more and more common in language acquisition. TTS clearly reads out the anthropomorphic sounds with adjusted speed and frequency. It then uses natural semantic analysis techniques generated by artificial

intelligence to make effective judgments on letters, words, the tone of numerals, and special reading methods. This makes it possible to pronounce every syllable clearly and organically. Language learners especially benefit from this technology since it gives them precise pronunciation models and enhances their listening abilities. SRT also enables students to practice speaking and get immediate feedback, which improves their language skills even more (Huang & Liao, 2020).

TTS software recognizes aloud text through speakers while simultaneously displaying the written text on a computer screen after recognizing the symbols on the page. A word is highlighted on the computer screen as it is being read out by the computer. The user is thus presented with a synchronized visual and audio display of the text (Staels & Van den Broeck, 2013). Unsurprisingly, these technological aids, like TTS software, have been shown to help slow readers read faster and understand what they read better (Higgins & Raskind, 2005). TTS technology can help struggling readers keep reading for a lot longer, and most importantly, it can make reading a lot less stressful (Elkind, 1998). Therefore, the primary purpose of this type of assistive technology is to mitigate deficiencies, not to rectify or remediate literacy difficulties, nor to educate or guide (Raskind & Higgins, 1999).

Educators are tasked with the responsibility of teaching students the skill of reading. Multiple experts have offered their viewpoints on the optimal methodology for instructing students in the skill of reading. Reading instruction places significant emphasis on phonemic awareness, which is currently being extensively incorporated into classroom practices. It is crucial to comprehend the significance of phonemic awareness in the development of proficient reading abilities. By providing guidance, instructors can enable students to strengthen their decoding and word recognition abilities by enhancing their capacity to identify and differentiate different sounds. Integrating phonemic awareness activities

into regular lessons can greatly enhance students' overall language development and comprehension abilities (Vetsch-Larson, 2022).

Children learn to read primarily through two kinds of knowledge: letters and sounds. These sources are represented by the more general conceptions of phonological awareness (phonemic awareness) and orthographic knowledge. Phonological awareness is the ability to reflect on and alter spoken language sounds (for example, /m/ is the initial sound in mop (Cain, 2010). Orthographic knowledge, on the other hand, refers to understanding the relationship between letters and sounds in written language. This includes recognizing letter patterns and understanding how they correspond to specific sounds. Together, phonological awareness and orthographic knowledge provide the foundation for children to decode and comprehend written text as they learn to read.

The way children depict these phonemes is at their discretion, as orthographic processing necessitates the capacity to obtain, retain, and implement letters and letter configurations (Apel, 2011). The comprehension of how letters represent phonemes in spoken language constitutes orthographic knowledge (Apel, Wolter, & Masterson, 2006). Early indicators of reading outcomes that are most robust are phonological awareness and orthographic knowledge (Treiman, 2006; Mol & Bus, 2011).

Understanding that letters represent phonemes (sounds) in spoken language is known as the alphabetic principle, and this principle, coupled with the ability to identify and manipulate phonemes, or phonemic awareness, are the fundamental building blocks of reading an alphabetic orthography. The National Reading Panel (2000) highlighted phonemic awareness as one of reading's *'big five notions*'.

**2. Literature Review:**

**2.1 Assistive Technology and Text-to-Speech (TTS)**

Decades of scientific research into the mental and behavioral factors that affect literacy learning has led to the development and testing of effective reading intervention programs for struggling readers. It has also led to the emergence of comprehensive guidelines and best practices for implementing an effective curriculum (Castles, Rastle & Nation, 2018; Daugherty, et al., 2014; Lovett, et al., 2017). Unfortunately, these practices that have been shown to be effective (like phonemic awareness and phonics) are not being incorporated into the present technological boom. For example, research on interventions consistently shows children with dyslexia benefit from direct instruction in phonological awareness and programs that make clear connections between orthography and phonology. On the other hand, children who are better at reading can often figure out the relationships between graphemes and phonemes without direct instruction (Storch & Whitehurst, 2002; Wanzek, et al., 2018; Vaughn, et al., 2008).

Researchers studying literacy development and reading disabilities should collaborate with tech developers to design tools based on extensive scientific literature on what works for struggling readers, test their effectiveness systematically, and contribute to the development of standards of practice for literacy-focused educational apps (Donnelly, et al., 2020).

**2.1.2 Assistive Technology**

Assistive technology (AT) encompasses services and devices that empower individuals with disabilities to complete daily tasks, facilitate communication, education, work, and recreation, ultimately fostering greater independence and improving their quality of life (Dell, Newton, & Petroff, 2016). Assistive technology therefore includes a wide spectrum of instruments, ranging from basic aids like wheelchairs and hearing aids to advanced equipment like voice recognition software and prosthetic limbs. These technologies are specifically tailored to cater to the unique requirements of those with disabilities, enabling them to actively engage in society and overcome any obstacles they may encounter.

The use of assistive devices for children with disabilities is classified into low-tech, mid-tech, and high-tech devices (Dell et al., 2017). Low-tech devices are easy to learn and do not require batteries or electronics. Mid-tech devices are battery-powered and user-friendly, such as calculators and audiobooks. High-tech advanced devices, like text-to-speech systems and smart devices, offer advanced features and functionalities that enhance productivity and accessibility. However, they require more technical knowledge and training to fully utilize their capabilities. The integration of these advanced devices into educational settings can greatly benefit students with special needs or learning disabilities (Taylor, Lohmann & Kappel, 2022).

AT is often employed to enhance the accessibility of various materials. TTS technology may convert printed text into audio format, allowing individuals who have difficulty accessing printed material to access the content. The National Assistive Technology Research Institute discovered that while schools do take AT into account at IEP meetings, it is less frequent for them to effectively carry out the process of assessing, selecting, implementing, and evaluating AT (Bausch, Ault, & Hasselbring, 2015). The absence of consistent action can lead to students being deprived of the essential assistive technology resources required for complete access to and understanding of the curriculum. Moreover, studies have demonstrated that the appropriate implementation of AT can greatly enhance student achievement and engagement.

AT can be employed to provide support for individuals with disabilities. For instance, nonverbal students can utilize communication devices to overcome their communication limitations. Similarly, students with print difficulties can rely on TTS software to facilitate their access to written information (Kennedy & Boyle, 2017). AT can also augment students' autonomy and engagement in the educational process. For instance, pupils who have physical disabilities can utilize assistive technology to gain access to resources and accomplish tasks that might otherwise pose difficulties for them. In addition, AT can enhance

inclusion by fostering a more comprehensive learning environment that enables all students to actively engage and make valuable contributions to classroom activities.

Students with dyslexia frequently employ assistive technology to lessen their challenges in areas where they suffer. Specifically, reading, writing, and spelling issues can be addressed with AT. Furthermore, dyslexic children can benefit from AT through having access to tools like speech recognition software and TTS, which can help them overcome difficulties with writing and reading. By making knowledge easier to access and boosting students' capacity to express ideas clearly, these assistive technologies raise academic success levels.

### 2.1.3 Text-To-Speech (TTS) Technology

TTS is a language processing software that transforms written text into audible voice, considering the specific language being utilized. TTS is utilized extensively in various contexts, including voice assistants, navigation systems, and accessibility solutions designed for those with LD children. It utilizes advanced algorithms to precisely articulate words and sentences, rendering it a significant tool for improving communication and accessibility in the modern digital era. According to Trivedi et al. (2018), TTS involves analyzing, processing, and understanding incoming text before converting it to digital audio and speaking it out. A text-to-speech synthesizer is a computer-based system capable of autonomously reading text (Sasirekha & Chandra, 2012).

According to Ren et al. (2019), TTS is a system that aims to produce coherent and understandable speech using written text. Modern TTS systems have the capability to imitate human speech patterns and intonations, resulting in generated speech that sounds more authentic and realistic. TTS has become a crucial element in various areas, such as entertainment, education, and customer service, because of these improvements. Ifeanyi, Ikenna, and Izunna (2014) also defined TTS as the conversion of written text into audible speech via artificial means. The synthesized speech can be tailored to accommodate many languages, accents, and even

individual voices, offering a varied and inclusive means of communication.

The ability to listen and understand speech in a foreign language is crucial for language learning. In the framework of computer-assisted language learning (CALL), TTS can be used for educational purposes, including creating exercises using dictation in other languages. Enhancing auditory perception skills requires these practices (Krasnova & Bulgakova, 2014). Additionally, interactive language learning resources like pronunciation exercises and listening comprehension tests can be made using TTS technology. By giving students the chance to hear and mimic native speakers, these resources can help them become more proficient language users overall.

Dutoit (1997) outlines the operational components of TTS. These components consist of the following: (1) Natural Language Processing (NLP), which combines the tone and rhyme of voice recordings of articles; and (2) Digital Signal Processing (DSP), which transforms symbol information received into speech. Zhu (2005) described in detail the four primary TTS modules.

1. *Textual Analysis*: Converts language characteristic parameters from an analysis of the syntax and semantics of the text. Put simply, the computer can recognize words, sentences, and pronunciations, as well as knowing the appropriate time and duration to halt when pronouncing.

2. *Rhythm Generator*: Language characteristic parameters, including the baseband track, volume, and duration, are transmitted to the rhythm generator to generate the corresponding rhythm message for each syllable in the text. Additionally, the rhythm generator converts pronunciation length, tone, voice, and pause mode into rhythmic parameters.

3. *Synthesis Unit Generator*: Generates output for the synthesis unit by analyzing speech waveform samples of monosyllabic phonemes from the speech database.

4. *Synthesizer for Text-to-Speech*: Opts for acoustic parameters that correspond to the noises that require pronunciation from the sound database.

There is a functional association between TTS and better accuracy, according to Young's (2017) study on TTS's role in helping students with learning difficulties improve their reading comprehension. For sixteen weeks, four participants received classroom-based text and TTS, and their performance improved over time. Participants' satisfaction with TTS for information acquisition was indicated by social validation questionnaires. The results include recommendations for further research as well as consequences for practice.

**2.2 Phonemic Awareness**

Before entering a classroom, students have already started to obtain the necessary skills required to become proficient readers. As stated by Snow, Burns, and Gryphon (1998), one of the most influential factors that affect the development of literacy is a child's overall health and the functioning of their sensory organs. The period in which language acquisition is possible is extremely short, therefore it is of the utmost importance that a child maintains good health. From the very beginning, children are exposed to words, sounds, and language from different sources in their surroundings. As they grow older, the connections between sounds and words gradually develop specific meanings as they reach different stages of development.

This process is supported by the child's ability to hear and see clearly. For instance, in case a child is encountering difficulties in their hearing or vision, it could considerably impede their language development as they might face challenges in accurately perceiving and interpreting the sounds and visual cues associated with language. Hence, early detection and intervention for any potential sensory issues are crucial in ensuring optimal literacy development in children. Dahmer (2010) asserts that individuals who have been exposed to phonemes, or the auditory units of language, from an early age possess the ability to establish connections between these sounds

and phonemes when they are deliberately instructed on the matter in the educational setting. The early exposure to phonemes functions as a stable groundwork for nurturing phonemic awareness, a vital skill in the domains of reading and writing. Pupils can use the information obtained in the classroom concerning phonemes to enhance their literacy skills.

Therefore, students are exposed to phonemes, or the phonemes of words, from their early childhood. According to Snider (1997), phonemic awareness serves as the vital link between the spoken language to which children are exposed from infancy and their ability to comprehend the "squiggles" on a page when the time comes for them to begin reading. It is essential to understand the meaning of the term "phonemic awareness," as it is frequently confused with the term "phonological awareness". Phonemic awareness pertains specifically to the capacity to discern and manipulate discrete phonemes within words, whereas phonological awareness comprises a more extensive array of abilities, such as rhyme and syllable recognition. The cultivation of phonemic awareness is critical for the optimal development of reading abilities and accurate word decoding in children.

Phonemic awareness pertains to the specific ability to focus on and manipulate individual sounds (phonemes) within spoken words. It is a subset of phonological awareness, which in turn is a subset of metalinguistic awareness (Chapman, 2003). In addition, Shanahan (2005) defined phonemic awareness as the "capability to perceive and manipulate the specific sounds contained within words" (p.6). If a child's sensory organs were not in good condition, this would be a challenging task. Phonological awareness serves as the fundamental skill upon which phonemic awareness is built. It refers to "the sensitivity to the phonological or sound structure of words." It includes the ability to distinguish between syllables, which is distinct from phonemic awareness (p.7).

Hearing and pronunciation are critical components in a child's phonemic awareness. Oral exposure to words and sounds is provided to children,

who are subsequently required to reproduce each phoneme with precision. Children phonics mastery would be exceedingly challenging in the absence of phonemic awareness, an additional critical skill that students must develop to become proficient readers (Brown, 2019). Phonics encompass the pedagogical approaches employed by an instructor to aid pupils in establishing associations between phonemes and letter sounds, with the ultimate objective of deciphering written words (Snow, Burns, & Gryphon, 1998, p.52). During previous times, phonemic awareness was not an essential requirement for instructing phonics. As a result, many students faced challenges when attempting to associate phonemes (*letters*) with phonemes (*sounds*).

Literacy instruction for typical primary stage concludes with the mastery of reading, following a progression from phonemic awareness to phonics. This process establishes the groundwork for their future literacy and is vital for the development of their reading abilities. Phonemic awareness serves as the vital link between the spoken language to which children are exposed from infancy and their ability to comprehend the "squiggles" on a page when the time comes for them to begin reading (Snider, 1997). Numerous studies revealed that phonemic awareness is crucial to second language learning. Koda (1998) hypothesized that L1 alphabetic experience is related to L2 phonemic awareness and decoding skills. Strong interconnections exist between reading comprehension, decoding, and phonemic awareness among Korean participants. Also, Vetsch-Larson (2022) examined the correlation between phonemic awareness growth and oral reading fluency in a first-grade classroom with mid-level students. Findings showed that with four weeks of small group intervention, students' average growth in oral reading fluency increased by nineteen words per minute.

TTS software has been found to be beneficial in enhancing reading skills for those with dyslexia. TTS can enhance phonemic awareness. In his study, Albreiki (2020) explores the utilization of interactive technology to improve the phonemic awareness abilities of Emirati kindergarteners. The results indicated a substantial

disparity in the proficiency of letter-sound association and sight word identification abilities between the experimental and control groups. The study emphasizes the significance of enhancing kindergartners' reading literacy through the development of phonemic awareness. Additionally, it provides suggestions for teachers and curriculum developers.

**2.3 Orthographic Knowledge**

Orthographic knowledge is widely recognized as a significant factor in word identification; therefore, it is also considered a plausible explanation for additional reading and orthography variability (Cutting and Denckla, 2001). Strong orthographic knowledge has been linked to faster and more accurate word recognition, which improves reading comprehension and fluency. Furthermore, orthographic knowledge is essential to spelling proficiency as individuals who have a firm grasp of the correspondence between letters and sounds are more likely to spell words correctly.

It is widely accepted that orthographic knowledge is learned by repeated exposure to print (Fletcher-Flinn and Thompson 2004; Stanovich and West 1989), but the underlying mechanisms are unclear. Orthographic representations of letter combinations and complete word units are stored in the mental lexicon because of regular exposure to printed information. To effectively recognize a word, one must understand how letters are combined to produce that word (Apel 2011; Loveall et al. 2013). This process entails recognizing and remembering patterns of letter sequences, as well as knowing spelling norms and conventions. Furthermore, research suggests that phonological awareness is important in establishing orthographic knowledge since it allows children to connect sounds to letters (Ehri 2005; Perfetti 2007).

In a broader context, the understanding of acceptable arrangements of letters is linked to orthographic knowledge (Perfetti, 1984). However, orthographic knowledge can be interpreted in various manners. To illustrate, one interpretation of orthographic knowledge is the capacity to identify printed arrangements of letters, specifically the structure of

words (Deacon, 2012; Georgiou et al., 2008). Another interpretation of orthographic knowledge is the comprehension of spelling patterns and rules, such as the knowledge of when to use "***i***" before "***e***" except after "***c***" (Treiman & Kessler, 2003). This more expansive interpretation includes not only the recognition of letter arrangements but also the understanding of how letters combine to form words and how spelling conventions are employed.

Another interpretation of orthographic knowledge is that it signifies the understanding of the regularities in visual and written language features (Roman et al., 2009). This comprehensive perspective of orthographic knowledge encompasses an awareness of the principles and patterns that govern spelling and visual representation of words. It also involves knowledge of common combinations of letters, phonetic patterns, and spelling errors. Orthographic knowledge is essential for the fluency of reading and writing as it enables individuals to swiftly recognize and decode words. Moreover, a strong grasp of orthographic knowledge can assist individuals in becoming more adept in spelling and enhancing their overall skills in written communication.

Orthographic word-likeness tasks are commonly used to assess general orthographic knowledge. In these tasks, children are required to pick the pseudoword that closely resembles a real word. One of the pseudowords follows proper orthographic conventions, while the other violates them. These tasks serve to gauge children's understanding of permissible orthographic patterns, rules regarding word position, and/or orthographic sequence rules (Apel et al., 2018). The purpose of these tasks is to measure children's knowledge of acceptable orthographic patterns, rather than their explicit application of that knowledge in reading or spelling. According to research findings, it is unlikely that children with reading and spelling difficulties will achieve higher scores on tasks that assess both word-specific and general orthographic knowledge, compared to their typically developing peers (Bergmann & Wimmer, 2008; Rothe et al., 2015).

Numerous investigations have revealed that the mastery of specific words and a more comprehensive understanding of orthography greatly contribute to the acquisition of word-reading skills (e.g., Rothe et al., 2015; Rothe, Schulte-Körne, & Ise, 2014). These studies indicate that the capacity to identify and interpret individual words, along with a more extensive comprehension of spelling patterns and rules, is indispensable for the development of skillful word-reading abilities. Furthermore, these studies highlight the importance of assessing and supporting the reading abilities of children by considering both specific word knowledge and general orthographic knowledge.

TTS technology can serve as an intervention for dyslexic children by transforming written text into spoken words. This enables them to listen to and understand the accurate pronunciation and spelling of words. Through the incorporation of technology in education, dyslexic children can enhance their reading and writing abilities more efficiently, hence improving their overall academic achievement. TTS software to enhance the orthographic proficiency of dyslexic children is currently a prominent trend. Research studies have demonstrated notable enhancements in reading accuracy and comprehension in dyslexic children who utilize TTS technology, thereby endorsing this approach. Staels & Van den Broeck's (2015) study investigated the impact of TTS on orthographic learning in disabled Dutch readers. The study involved 65 readers reading eight stories with embedded homophonic pseudoword targets, with or without the software. The results showed that orthographic learning was present during independent silent reading, with target spellings being correctly identified, named, and spelled more accurately than their homophone foils. This supports the hypothesis that all readers, even poor readers of transparent orthographies, can develop word-specific knowledge. However, the study also found a negative effect of text-to-speech software on orthographic learning, attributed to passively listening to the auditory presentation of the text.

The study of Park, et al. (2017) investigates the impact of TTS software on 9th grade struggling readers' unassisted reading performance. The researchers used an experimental design and 164 students from 30 Hawaii teachers participated. The results showed a significant positive effect on student reading vocabulary and comprehension after 10 weeks of TTS software use. Although the study has limitations, it suggests the need for further research on TTS software as a viable reading intervention for adolescent struggling readers. The findings highlight the potential benefits of TTS software in facilitating reading access for struggling readers.

In their study, Svensson et al (2021) examined the impact of assistive technology, including tablets with Text-To-Speech and Speech-To-Text apps, on students with severe learning disabilities (reading and writing). The study involved 149 participants, with the intervention group receiving 24 training sessions and the control group receiving usual treatment. Both groups improved significantly in one year, but gains did not differ directly or at one year of follow-up. Findings revealed that assistive technology is supportive and increases motivation for schoolwork, but also highlighted challenges in measuring text assimilation and communication.

**2.4 LD Children (Dyslexics)**

Dyslexia is a neurological condition that involves difficulties in reading, recognizing words, decoding, and spelling, despite having normal cognitive capacity and access to suitable education (International Dyslexia Association, 2002). Students diagnosed with dyslexia frequently encounter difficulties in accessing and comprehending written material, underscoring the importance of providing them with suitable assistive technology aids. However, if there is not an appropriate continuation of actions, these pupils may not obtain the essential assistive technology accommodations they require. Research consistently shows that the implementation of AT can significantly enhance student academic performance and classroom involvement.

Dyslexia is distinguished by inadequacies in the recognition, interpretation, spelling, and understanding of words (Smirni et al., 2020). The process of word recognition entails two cognitive functions: phonological function and visual recognition (Cheng et al., 2021). Phonological processing encompasses the transliteration of phonemes, while visual perception entails the identification of written units (Zhao et al., 2018). Both functions are essential during the early stages of learning to read, when children begin to understand the symbolic nature of written symbols (Cai et al., 2020). As the acquisition process advances, the path towards lexical recognition commences, where words are recognized based on their written characteristics (Wang & Bi, 2022). The link between acquiring reading skills and processing sounds is proven by establishing a direct relationship between auditory units and written and visual representations (Zhao et al., 2018). Comparative studies between experienced readers and individuals with dyslexia demonstrate a correspondence between phonological and visual abilities. Phonological ability extends beyond the phonemic connection and instead reflects the capacity to decode the relationship between represented elements and sounds in a linear manner (Smirni et al., 2020). Dyslexia often arises from a deficiency in dual decoding, which necessitates the ability to decode both the phonetic encoding and the mental representation of words (Wang & Bi, 2022).

Extensive research has demonstrated that targeted phonological training is advantageous for students who struggle with severe reading impairments (Fälth, et al., 2013; Torgesen, et al., 2001). Enhancing phonological awareness includes enhancing abilities associated with identifying and manipulating sounds in words, such as phonemic awareness and phonics. By focusing on these particular areas, children who struggle significantly with reading can cultivate the fundamental abilities required for achieving success in reading. Moreover, offering timely intervention and continuous assistance can avert the adverse

effects of these challenges on individuals' overall educational and professional paths.

**Hypotheses of the Study:**

The current study tries to validate the following hypotheses:

1. There are statistically significant differences in the rank of pupils' mean scores of phonemic awareness in both experimental and control groups of dyslexic children in favour of the experimental group.
2. There are statistically significant differences in the rank of pupils' mean scores of orthographic knowledge in both experimental and control groups of dyslexic children in favour of the experimental group.

**Methods:**

**Participants:**

The study involved a sample of dyslexic children recruited from two classes in one of LD schools in Hurghada, Red Sea Governorate. Participants consists of 20 dyslexic children who were randomly distributed to experimental group (9) children and control group (11) children (M= 11.97, SD=0.46). Participants were selected based on established criteria for dyslexia, including a confirmed diagnosis through standardized assessments and diagnostic tools. Informed consent was obtained from both participants and their guardians before their inclusion in the study.

**Inclusion Criteria:**

The researchers established criteria to determine pupils to include in this study. The participants selection was based on the following criteria: (a) included participants with LD or both phonemic awareness and orthographic knowledge (i.e., scored below expected grade level in reading achievement or below 30% on standardized tests of phonemic awareness and orthographic knowledge).

**Measures:**

The researcher designed and used the following tools in order to achieve the study objectives:

**1. The Phonemic Awareness Test for dyslexic children:**

**The aims of the Test:** The Phonemic Awareness Test for Dyslexic Children (PATDC) was designed to assess the phonemic awareness skills of 5th-grade dyslexic children in Egypt. Phonemic awareness is the ability to recognize and manipulate the individual sounds (phonemes) in spoken words, which is a crucial skill for developing reading and spelling abilities.

**Test Objectives:** PATDC aims to achieve the following objectives:

1. Evaluate the ability to identify the first sound in a given word.
2. Assess the skill of recognizing the middle sound within a word.
3. Measure the capacity to identify the last sound in a given word.
4. Evaluate the skill of combining individual sounds to form complete words.
5. Assess the ability to break down a word into its individual phonemes.

**Description of the Test:** The test comprises five parts, each focusing on a specific aspect of phonemic awareness, 5 items each part. The total score of the test is 25 marks The questions are multiple-choice, with each question offering four answer choices. The content is tailored for 5th-grade dyslexic children in Egypt, considering their linguistic context and developmental stage.

**2. The Orthographic Knowledge Test for dyslexic children:**

**Aim of the Test:** This Orthographic Knowledge Test for Dyslexic Children (OKTDC) aims to comprehensively evaluate various aspects of orthographic knowledge in dyslexic children, including word recognition, decoding skills, reading fluency, and comprehension. The test is designed to provide a thorough understanding of the child's reading abilities, allowing for tailored interventions and support.

**Test Objectives:** The OKTDK aims to achieve the following objectives:

- Evaluate word recognition skills.

- Assess the ability to comprehend and complete sentences with real words.
- Assess decoding skills by decoding and reading pseudowords.
- Evaluate the ability to construct meaningful sentences using pseudowords.
- Measure fluency in reading by assessing the ability to read a passage with ease.
- Evaluate reading speed through a timed real word reading task.
- Assess comprehension skills through questions related to a given passage.
- Evaluate inferential comprehension by determining the meaning of a word in context.

**General Description of the Test:** The OKTDK consists of four sections, each focusing on different aspects of orthographic knowledge: 1) real word reading (through word recognition and sentence completion tasks), 2) pseudoword reading skills with decoding and sentence construction tasks, 3) reading fluency, (assessing both overall fluency and reading speed), 4) reading comprehension. The OKTDK total score is 30 points; real word reading (5 marks), pseudoword reading skills (5 marks), reading fluency (10 marks), and reading comprehension (10 marks).

**Test Administration Guidelines:** The following guidelines were followed to administer the test:

1. Administer the test in a comfortable reading environment.
2. Use appropriate accommodation for dyslexic children, such as additional time or visual aids.
3. Include a mix of familiar and unfamiliar content to assess generalization of skills.

**Procedures:**

After a full search for the best Text-to-Speech software and websites, the researchers decided to use "NaturalReader" (https://naturalreaders.com/) to help dyslexic children to transform texts into audio in an endeavor to

improve their phonemic awareness and orthographical knowledge of the 5th grade dyslexic children.

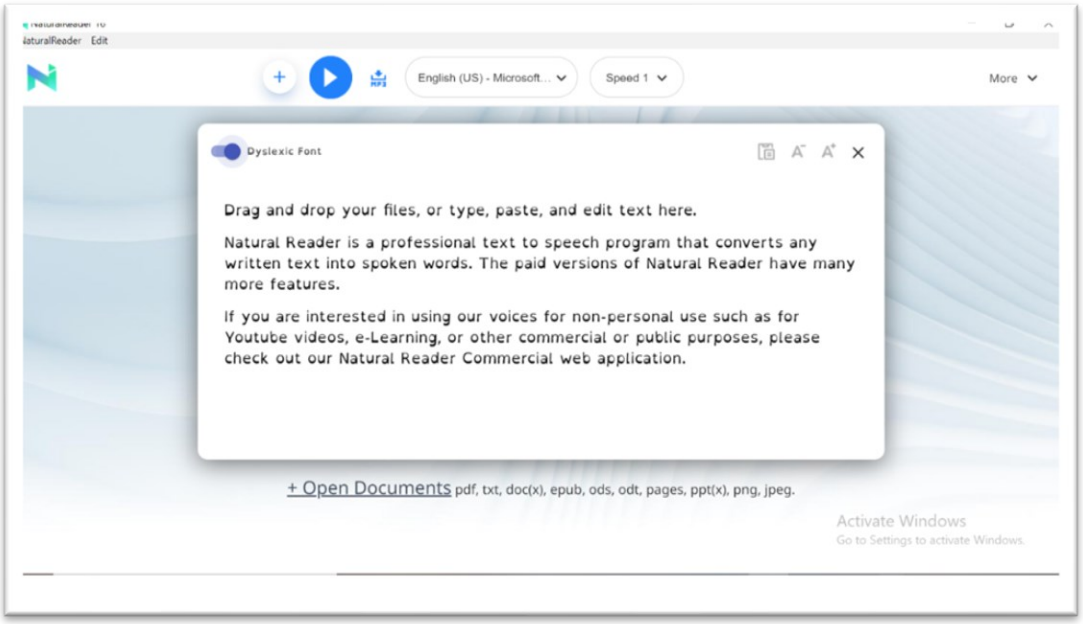


**Fig. 1** A screenshot of the NaturalReader software

NaturalReader is an app that converts text documents into speech using high-quality, natural-sounding voices. It is designed to enhance accessibility, particularly beneficial for individuals with dyslexia or those struggling with reading on digital devices. The app offers practical features like marking the page you've read, adjusting speech speed, and providing an auditory experience for reviewing and correcting written texts or speeches. The latest addition, the Pronunciation Editor, enhances voice quality and improves the reading of acronyms. This innovation reflects NaturalReader's commitment to continually improving and innovating, offering users a more refined and effective text-to-speech experience.

The researchers have developed a comprehensive list of vocabulary based on the school textbook "*Connect*". This list has been carefully selected to cater to the phonemic and orthographic awareness requirements of dyslexic children in fifth grade in primary school. This comprehensive list encompasses a wide range of skills essential for

developing phonemic and orthographic awareness. It includes aspects such as initial, final, and medial sounds, blending and segmenting words, rhyming, word families, syllable awareness, word endings, prefixes and suffixes, homophones, contractions, common spelling patterns, sight words, compound words, homonyms, antonyms, irregular plurals, contrasting sounds, and vowel digraphs. The selection of these vocabulary terms is carefully planned to match the developmental stage and learning requirements of dyslexic children, offering them abundant chances to practise and strengthen crucial literacy abilities. Integrating these terms into exercises can effectively bolster the literacy improvement of dyslexic children, enhance their reading and spelling proficiencies, and ultimately augment their overall academic achievement.

**Data Analysis:**

Since the main objective of the current study is to investigate the effectiveness of Text-to-Speech (TTS) on improving Phonemic Awareness and Orthographic Knowledge of Dyslexic Childre, obtained data will be analyzed to assess the impact of the intervention on the posttesting of the target variables. Therefore, the following data analysis methods will be employed: 1) *descriptive statistics*, including means, medians, and standard deviations, for pre- and post-intervention scores of the Phonemic Awareness Test for Dyslexic Children (PATDC) and the Orthographic Knowledge Test for Dyslexic Children (OKTDC). 2) *pre- and post-intervention comparison* to stand on the effectiveness of TTS software using t-Test. paired samples t-tests to examine statistically significant differences between pre- and post-intervention scores for both PATDC and OKTDC. 3) *Correlation Analysis*: The correlation between changes in phonemic awareness (PATDC) and orthographic knowledge (OKTDC) scores post-intervention. This will help understand the relationship between improvements in these two areas. This data analysis aims to provide robust evidence regarding the impact of Text-to-Speech intervention on phonemic awareness and orthographic knowledge in dyslexic children,

contributing valuable insights to both research and practical applications in educational settings.

**Results:**

Results of the first hypothesis showed that there are statistically significant differences in the rank of pupils' mean scores of phonemic awareness in both experimental and control groups of dyslexic children in the posttesting of the phonemic awareness test of dyslexic children in favour of the experimental group. Table (1) shows *t*-test results of the differences between the mean scores of the experimental and control groups in the posttesting of phonemic awareness test.

**Table (1)** *t*-test results of the differences between the mean scores of the experimental and control groups in the posttesting of phonemic awareness test (N=20)

| Test | N. | Mean | Std. Deviation | t-test value | Df | p-value |
|---|---|---|---|---|---|---|
| **Control** | 11 | 15.5 | 3.2 | 2.15 | 18 | 0.045 |
| **Experimental** | 9 | 18.9 | 3.7 | | | |

Table (1) shows that there are differences between the mean scores of the experimental (M= 18.9, SD = 3.7), and control groups (M = 15.5, SD = 3.2) in the posttesting of phonemic awareness test which denote that the Text-to-speech application was effective on improving phonemic awareness of Egyptian dyslexic children.

Also, findings validated the second hypothesis showed that there are statistically significant differences in the rank of pupils' mean scores of orthographic knowledge in both experimental and control groups of dyslexic children in the posttesting of the orthographic knowledge test of dyslexic children in favour of the experimental group. Table (2) shows *t*-test results of the differences between the mean scores of the experimental and control groups in the posttesting of orthographic knowledge test.

**Table (2)** *t*-test results of the differences between the mean scores of the experimental and control groups in the posttesting of orthographic knowledge test (N=20)

| Test | N. | Mean | Std. Deviation | t-test value | Df | p-value |
|---|---|---|---|---|---|---|
| **Control** | 11 | 19.8 | 3.1 | 2.35 | 18 | 0.032 |
| **Experimental** | 9 | 22.3 | 2.3 | | | |

Table (2) shows that there are differences between the mean scores of the experimental (M= 22.3, SD = 2.3), and control groups (M = 19.8, SD = 3.1) in the posttesting of orthographic knowledge test which denote that the Text-to-speech application was effective on improving orthographic knowledge of Egyptian dyslexic children.

Table (3) shows that there is a strong positive relationship between phonemic awareness skills and orthographic knowledge among dyslexic children.

**Table (3)** Pearson correlation coefficients between phonemic awareness skills and orthographic knowledge among dyslexic children.

| | | Phonemic Awareness | Orthographic Knowledge |
|---|---|---|---|
| **Phonemic Awareness** | Pearson correlation | 1 | 0.504* |
| | Sig. (2-tailed) | | 0.012 |
| | N. | 20 | 20 |
| **Orthographic Knowledge** | Pearson correlation | 0.504* | 1 |
| | Sig. (2-tailed) | 0.012 | |
| | N. | 20 | 20 |

*. Correlation is significant at the 0.05 level (2-tailed)

Pearson correlation coefficients suggest that there is a strong positive relationship between phonemic awareness skills and orthographic knowledge among dyslexic children. In other words, dyslexic children who perform well on the Phonemic

Awareness Test tend to also perform well on the Orthographic Knowledge Test, and vice versa.

**Discussion:**

Findings indicate notable disparities in the mean scores between the experimental and control groups throughout the posttesting stage, namely in the areas of phonemic awareness and orthographic understanding among dyslexic pupils. Although the disparities in the mean scores are not substantial, they are nonetheless statistically significant. The findings indicate that the intervention employed in the study potentially had a beneficial effect on enhancing phonemic awareness and orthographic understanding in students with dyslexia. Additional investigation utilizing a more extensive sample size could yield more definitive proof regarding the efficacy of this intervention.

This can be linked to the impact of the training that dyslexic children obtained by utilizing a TTS. TTS technology allows students to have their texts and learning materials spoken aloud, thereby reducing impediments and establishing a more inclusive learning environment. This is especially advantageous for kids who face learning difficulties or have visual impairments. Moreover, the utilization of TTS might further augment reading comprehension and fluency abilities in children with dyslexia. Through accurate pronunciation of words, students can enhance their comprehension of the text, resulting in enhanced reading proficiency. Moreover, this technology has the potential to enhance the autonomy of dyslexic students as learners by allowing them to retrieve knowledge without being completely dependent on their reading abilities.

TTS technology is improving reading accessibility for individuals with special needs, including visual and hearing impairments and dyslexia. Games like Forza 5 Horizon now feature built-in sign interpreters for deaf players and wearable tech-sleeves that convert sign language into spoken words. Screen readers enhance accessibility for educational and recreational purposes. TTS technology can enhance literacy, reading,

and writing skills, including listening, speaking, reading, writing, and sound discrimination. Read-aloud and TTS technologies use playback controls, auto-scroll, and auto-highlight features to assist readers in tracking text. These technologies also aid those with learning problems, such as dyslexia, by providing alternative methods to access and comprehend text. Additionally, TTS technology benefits those with visual impairments by enabling them to access written information without relying solely on their vision (Okumoko, 2022).

The current technology boom is mostly neglecting to integrate key evidence-based approaches, such as phonemic awareness and phonics. Research consistently shows that children with dyslexia benefit from direct instruction in phonological awareness and curricula that establish clear connections between orthography and phonology. On the other hand, children with stronger reading skills can often deduce grapheme-phoneme correspondences without explicit instruction. Extensive literature supports the significance of phonics and phonemic awareness in reading (Bradley & Bryant, 1983; Foorman, et al., 1998; Lovett, et al., 2017; Torgesen, et al., 2001).

Dyslexic students often struggle with decoding, which may not necessarily indicate their comprehension level. Failure to address decoding deficits can negatively impact their academic success. Although Structured Literacy can improve decoding and comprehension skills, some students still struggle with reading. Therefore, comprehensive reading aids are crucial for students with dyslexia to mitigate the impact of poor literacy skills on academic achievement, self-efficacy, and future success (Flynn, Zheng, & Swanson, 2012; IDA, 2017; Spear-Swerling, 2019; Undheim, Wichstrom, & Sund, 2011). Although there is limited information available about the specific populations that benefit from TTS (Alper & Raharinirina, 2006), Strangman and Dalton (2005) propose that students with limited word recognition but strong comprehension skills may derive greater advantages from TTS compared to students who struggle with both decoding and comprehension.

According to the findings of this study, the utilization of TTS technology enhances the ability of dyslexic children to recognize and differentiate individual sounds in words. This aligns with prior research, as one such study demonstrated that providing Phonemic segmentation training together with education on letter names and sounds to kindergarten students has a positive impact on enhancing both reading and spelling abilities. Teaching phoneme awareness results in enhanced early reading and spelling abilities, whereas education in language activities did not have the same effect (Ball & Blachman, 1991).

In addition, orthographic learning in disabled readers using transparent orthography and TTS software has shown to be effective on learning process. Orthographic learning was present during independent silent reading, with target spellings being correctly identified, named, and spelt more accurately than their homophone foils (Staels & Broeck, 2015). This research contradicts the current study's findings that TTS technology improves orthographic Nevertheless, because TTS software just listened to the text's auditory presentation, it had a detrimental impact on orthographic learning.

**Conclusions:**

Phonemic awareness is considered to be more than just a part of initial reading training. This viewpoint asserts that achieving "phonemic proficiency," demonstrated by mastery of abilities such as phoneme elision or substitution, is a crucial objective for assessment and instruction that extends beyond the early grades. The perspective, which has affected state policy on reading teaching, emphasizes the importance of daily phonemic awareness instruction that is not limited to print materials (Clemens, et al., 2021). Recently, viewpoints have surfaced that see phonemic awareness as a specific area of instruction that ought to proceed much beyond the first two years of school, rather than merely as a talent that helps with word reading.

In a related context, the ability to recognize written letter strings quickly and almost effortlessly is a sign of proficient reading. The development

of word-specific orthographic representations connected to phonological, semantic, morphological, and syntactic information is the primary prerequisite for this fluency. One of the main concerns in literacy practice and research is the creation of orthographic representations. Effective instruction and intervention depend on an understanding of how these representations are created and incorporated into the reading process. Furthermore, researching the variables that affect the formation of orthographic representations can offer important insights on enhancing reading abilities in those who struggle with reading (Share, 2004).

These viewpoints, which are represented in well-known initiatives and recommendations (Heggerty & VanHekken, 2020; Kilpatrick, 2018, 2020; Kilpatrick & O'Brien, 2019), support extending the time spent on phonemic awareness exercises in the classroom for students who struggle with reading past the first grade and into the upper elementary grades. Recently, viewpoints have surfaced that see phonemic awareness as a specific area of instruction that ought to proceed much beyond the first two years of school, rather than merely as a talent that helps with word reading. These viewpoints, which are represented in well-known initiatives and recommendations (Kilpatrick, 2020; Kilpatrick & O'Brien, 2019), support extending the time spent on phonemic awareness exercises in the classroom for students who struggle with reading past the first grade and into the upper elementary grades.

Reading fluency, encompassing the abilities of word recognition and decoding, serves as a crucial link to reading comprehension (Breznitz, 2006). Word recognition speed is a contributing component that aids in the process of obtaining meaning from text (Torgesen, Rashotte, & Alexander, 2001). Differences in a student's word recognition are frequently determined by variations in processing speed (Breznitz, 2006). Research indicates that the effective handling of orthographic, phonological, and semantic information enhances the automatic recognition of words and, ultimately, comprehension (Goswami, 1999). Therefore, employing instructional

tools to alleviate the task of decoding could be beneficial in facilitating comprehension.

Technological tools can scaffold learning in the classroom by providing limitless practice that optimizes for individual readers' strengths and weaknesses. Modern computational tools, such as speech recognition and synthesis APIs, allow for embedded tools to be provided in real-time for any given text. Text-to-speech is one tool that assist dyslexic children to develop their literacy skills. These technologies focus on the phoneme and syllable level, benefiting reading performance and adhering to known learning and pedagogical principles (Cheung & Slavin, 2013; Messer & Nash, 2018; Seward, et al., 2014)

TTS is regarded as an advanced assistive technology reading assistance (Bouck, 2017). This technology enables users to listen to digital text by converting it into synthetic voice (Anderson-Inman, & Horney, 2007). The potential value of assistive technology, such as TTS, for individuals with reading difficulties is grounded in learning theories such as Cognitive Load Theory (CLT) (Pollock, Chandler & Sweller, 2002) and Automaticity Theory (LaBerge & Samuels, 1974). Based on the CLT, optimal learning occurs when information is supplied in a manner that can be efficiently processed in working memory (Chandler & Sweller, 1991). This is particularly relevant to reading because it is an intricate process that places significant strain on working memory (Swanson & Siegel, 2001). When word identification is not automatic, the act of reading becomes sluggish, requiring significant cognitive effort and straining memory capacity (LaBerge & Samuels, 1974).

Therefore, TTS technology can potentially alleviate cognitive load and enhance automaticity for individuals who struggle with reading. Research has shown that students who use TTS technology have experienced improvements in the amount of text they read, while also reducing feelings of fatigue and stress (Hodapp & Rachow, 2010). Additionally, slower readers have been able to increase their reading speed with the help of TTS (Sorrell, Bell, & McCallum, 2007).

**Limitations & Future Research:**

The study's generalizability may be compromised by factors such as the limited sample size, the demographics of the participants, and the specific characteristics of the TTS instruments employed. Conducting additional study using larger and more diverse samples would be advantageous in order to ascertain the wider relevance of the findings. Furthermore, the current study is limited by a brief intervention time. The duration of the intervention, which spans 10 weeks, may not provide the time to comprehensively assess the enduring impact of TTS technology on language acquisition in individuals with dyslexia. Subsequent investigations may explore extended intervention durations to evaluate enduring enhancements over a prolonged timeframe.

The third constraint pertains to the assessment instruments. Although phonemic awareness and orthographic knowledge tests were employed to evaluate alterations in linguistic ability, it is important to note that these measures may not comprehensively reflect the intricacies of language acquisition and dyslexia. Supplemental evaluation instruments or a blend of methodologies could yield a more thorough comprehension of the effects of TTS technology. However, it is important to note that despite the inclusion of a control group that received traditional language training, the differences in how the experimental and control groups were taught and the resources they had access to could potentially introduce factors that could affect the results and make them less reliable. Enhancing the stringency of control procedures could bolster the credibility of the study's findings.

**Further Research:**

Based on the results of the current study as well as its limitations, the following research should be conducted:

1. Longitudinal Studies: Conducting longitudinal studies to monitor participants' improvement over a prolonged duration would provide valuable insights into the enduring efficacy of TTS therapies. Assessing results beyond the intervention time can offer a more distinct

understanding of the enduring advantages and possible obstacles linked to TTS technology.

2. Examining the diversity of TTS tools: Analyzing several categories of TTS tools and their distinct attributes may facilitate the identification of the most impactful aspects in aiding language acquisition for individuals with dyslexia. An analysis of different TTS systems and customization choices could provide valuable insights for creating personalized interventions.

3. Evaluating the effectiveness of TTS technology in enhancing linguistic skills in various languages and language structures helps broaden the generalizability of the results to other populations. Gaining insight into the interaction between TTS therapies, linguistic variances, and writing systems can provide valuable knowledge for developing culturally responsive educational approaches.

4. Tailored Approaches: Investigating customized methods for TTS intervention, such as adaptive learning modules or personalized feedback mechanisms, can enhance the efficiency of TTS technology for individuals with dyslexia. Customizing interventions to the distinct requirements and cognitive preferences of each participant can optimize learning results and foster active involvement.

5. Integration with Classroom Practices: Exploring methods to incorporate TTS technology into classroom settings and educational curriculum can promote its extensive acceptance and use. Joint research conducted by educators, instructional designers, and technology developers can provide valuable insights on the most effective methods for integrating TTS (Text-to-Speech) systems into inclusive learning environments.

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