Computer-Assisted Multisensory Reading Intervention in Children with Dyslexia

Ramazan Eryilmaz[1], Emine Balcı[1]

[1] Alanya Alaaddin Keykubat University, Turkey

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CORRESPONDING AUTHOR:
Emine Balcı;
emine.balci@alanya.edu.tr
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ABSTRACT:

Children diagnosed with dyslexia have been found to encounter significant challenges in reading skills compared to their peers. Existing literature examining dyslexia in children has sought to elucidate the cognitive model of reading as a skill and the development of reading abilities concerning typical readers of comparable age. This study aims to examine the effects of computer-based multisensory reading training on the reading performance of students with dyslexia. To achieve this, a six-week intervention program was implemented, during which dyslexic students participated in multisensory reading activities three days a week. The primary focus of the research was to compare several key reading-related skills between students with dyslexia and their non-dyslexic peers. These skills included rapid automatized naming, the ability to read both meaningful and non-meaningful words, reading speed, reading comprehension, mechanical reading, and phonological awareness. The performance of dyslexic children (n = 170) and non-dyslexic children (n = 170) was assessed based on their scores in their native language. All participants were in grades 1 to 4 of elementary school, with groups matched for grade level, age, and gender. This study reveals partial differences in rapid automatized naming and significant differences in phonological awareness between dyslexic and typically developing children. Dyslexic students demonstrated improvement in word reading, particularly with both meaningful and meaningless words. However, a significant gap in reading comprehension was found, with typically developing students outperforming their dyslexic peers. Additionally, the study highlighted differences in reading speed, with typically developing students typically reading faster than dyslexic students.

Keywords: Learning Difficulty, Reading, Dyslexia, Multisensory, Computer-Assisted.

INTRODUCTION

Dyslexia is a common reading disorder that affects a significant proportion of school-age children and persists into adulthood, characterized by persistent difficulties with written materials (Marchesotti et al., 2020). It is a prevalent learning disability, affecting 5-17% of children, with prevalence rates varying depending on its definition (Elliott & Grigorenko, 2014; Ozernov-Palchik & Gaab, 2016). Family studies suggest that dyslexia is hereditary, occurring in 68% of identical twins and 40-60% of individuals with a first-degree relative who has dyslexia (Grigorenko, 2004).

The definition of dyslexia has evolved over the years, as there is no clear and universally agreed diagnostic criterion (Rose, 2009; Snowling & Melby-Lervåg, 2016). However, it is essential to note that reading abilities in the general population follow a continuous distribution, and the "cutoffs" used to describe a person as "dyslexic" are arbitrary (Pennington, 2006). Furthermore, dyslexia is sometimes accompanied by other language disorders, such as Specific Language Impairment (SLI) (Bishop & Snowling, 2004; Melby-Lervåg & Lervåg, 2012), speech sound disorders (Pennington & Bishop, 2009), and Attention-Deficit/Hyperactivity Disorder (ADHD) (McGrath et al., 2011). In line with this, the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders* – Fifth Edition (DSM-5; American Psychiatric Association, 2013) groups reading disorders (dyslexia), mathematical disorders, and procedural disorders under a broader category of Specific Learning Disorder within the neurodevelopmental disorders section.

The complexity of learning to read and the challenges individuals face in this process play a crucial role in understanding dyslexia. Dyslexia is not merely limited to reading difficulties, but it also affects various aspects of language processing (Snowling & Melby-Lervåg, 2016). As such, it can be described as a learning disorder with significant implications for educational practices. Early diagnosis and intervention are crucial for individuals with dyslexia, as the definition and diagnostic process directly influence the educational strategies employed. Tailored educational plans and support strategies are vital for effectively addressing the needs of students with dyslexia (Torgesen, 2000).

Educational interventions for students with dyslexia aim not only to improve reading skills but also to enhance the individual's overall learning abilities. Early interventions play a significant role in the academic success of individuals with dyslexia, enabling them to achieve greater success in their educational careers. Additionally, societal perceptions and individual attitudes toward individuals with dyslexia play a significant role in shaping their experience. It is evident that dyslexia is not simply a challenge related to reading and writing but also involves broader life challenges and opportunities, influencing social interactions and personal development (Shaywitz & Shaywitz, 2005).

Reading requires the ability to decipher a phonetic code to understand the relationship between letters and sounds. Dyslexia is the expression of a particular problem in converting individual speech sounds (phonemes), such as the /s/ sound or /m/ sound, into written symbols (graphemes). Children with dyslexia may also have trouble reading fluently, which can result in accurate but slow and tedious reading (Integra, 2009). Dyslexia, by definition, is a reading disorder that is difficult to disappear completely (APA, 2013). Children with dyslexia experience difficulties with both reading accuracy and fluency, as well as spelling problems (Bates et al., 2007; Ehri, 2005; Tilanus et al., 2019).

Decades of research have confirmed that children with dyslexia experience significant difficulties in various aspects of reading, including fluent reading, speed and mechanical reading, reading comprehension, and phonological awareness (Locascio et al., 2010). Fluent reading, reading speed, mechanical reading, reading comprehension, and phonological awareness are all interconnected components of the reading process. Fluent reading refers to the ability to read smoothly and efficiently without excessive effort, allowing the reader to focus on comprehension rather than decoding individual words (Kuhn & Stahl, 2003). This fluency is closely tied to reading speed, which measures how quickly one can read, and mechanical reading, which emphasizes the decoding of written symbols into spoken language (Perfetti, 1985). However, reading speed and mechanical reading alone do not guarantee understanding, as they must be paired with reading comprehension – the ability to interpret, analyze, and derive meaning from the text, which requires integrating prior knowledge and cognitive skills (Snow, 2010).

Additionally, phonological awareness plays a foundational role in all these processes, as it involves the ability to recognize and manipulate sounds at different levels, such as phonemes and syllables, which are essential for decoding and understanding language (Stanovich, 2000). Together, these concepts form the basis of proficient reading and influence one another in complex ways. Behavioral research suggests that these deficits are related to difficulties in executive functioning (Stanovich, 2000; Berninger et al., 2008), but no empirical study has identified which neural pathways may contribute to the reading comprehension deficits found in children with dyslexia. The reading comprehension deficits observed in children with dyslexia can help explain why reading comprehension is more challenging for them. Children with dyslexia often struggle with decoding words, which is a fundamental skill necessary for fluent reading. This difficulty in word recognition hampers their ability to focus on higher-level processes, such as understanding and interpreting the meaning of text (Shaywitz & Shaywitz, 2005). As they spend more cognitive resources on decoding individual words, less attention is available for integrating information, making inferences, and retaining key details from the text, all of which are essential components of reading comprehension (Snow, 2010).

Furthermore, phonological awareness, which is often impaired in individuals with dyslexia, plays a significant role in decoding and understanding written language, making it even harder for them to comprehend what they read (Stanovich, 2000). Therefore, the underlying deficits in decoding, phonological awareness, and fluency contribute to the challenges children with dyslexia face in achieving proficient reading comprehension. On the other hand, children with dyslexia exhibit deficiencies in their working memory, phonological awareness, and word-reading skills (Berninger et al., 2008; Swanson et al., 2009). Working memory affects both phonological awareness and word reading efficiency greatly (De Abreu et al., 2011; Christopher et al., 2012; Locascio et al., 2010). According to studies, phonological awareness has a significant impact on word reading activity (Melby-Lervåg et al., 2012), and phonological working memory is associated with word reading (Gathercole & Baddeley, 2014; Knoop-van et al., 2018). Reading a text that is meaningful and contextually appropriate engages a variety of complex cognitive and linguistic processes. The Simple View of Reading (SVR), as proposed by Gough and Tunmer (1986) and Hoover and Gough (1990), posits that individual differences in reading comprehension are primarily explained by two core skills: word decoding (the ability to identify words in written text correctly) and language comprehension (such as the ability to understand spoken language). While this model has been influential in reading research, critics argue that it oversimplifies the complex nature of reading comprehension by failing to consider other crucial cognitive processes, such as inference-making and the integration of background knowledge (Cain & Oakhill, 2011). Although decoding and language comprehension are related, they remain distinct and separable skills in the reading process, with their combined effect accounting for much of the variability in reading comprehension performance across development (Catts et al., 2003; de Jong & van der Leij, 2002). This simplification of the reading process overlooks the broader cognitive mechanisms involved in understanding text, especially for individuals with dyslexia.

Crain and Shankweiler (1990) suggested that individuals with dyslexia experience slowed fluency and challenges in content analysis during reading, which subsequently hinder their comprehension and negatively affect their reading performance. As a result, children with dyslexia not only struggle with slower reading rates and less accuracy but also tend to use fewer reading comprehension strategies compared to their typically developing peers (Knoop-van Campen, 2022). This claim warrants further exploration—whether these deficits arise from a lack of instruction, cognitive overload, or other underlying factors. Hoover and Gough (1990) argue that reading comprehension is a product of both language comprehension and analytical skills. As children become more proficient at decoding over time, they are better able to focus their cognitive resources on comprehension. However, this process extends beyond simple word recognition, involving the ability to understand words in the context of sentences and to derive new information from the text.

Moreover, reading comprehension also involves higher-order cognitive processes, such as making inferences, integrating prior knowledge, and monitoring for coherence, which is essential for fully understanding the material (Perfetti & Stafura, 2014). Expanding upon these elements provides a more nuanced view of the reading process, which is particularly relevant for children with dyslexia who often struggle with these complex cognitive functions. Bridging these insights with the Simple View of Reading would offer a more comprehensive understanding of the challenges that children with dyslexia face in developing effective reading comprehension skills. In this context, children with dyslexia often receive audio support through the narration of written text to compensate for their lack of accurate and fluent decoding. However, it is essential to specify whether this support leads to general improvements across all contexts or if its effectiveness depends on factors such as the child's vocabulary level or working memory capacity. Understanding the role of these individual differences in the efficacy of audio support can provide more targeted interventions, helping to better address the specific needs of children with dyslexia in developing both decoding skills and higher-order cognitive processes crucial for reading comprehension.

Wood et al. (2018) conducted a meta-analysis on the effects of using text-to-speech (digital reading aloud in addition to written text) on general reading comprehension, showing that audio support has the potential to improve comprehension in children with decoding difficulties. According to Perfetti (1985) and Perfetti and Hart (2002), fluent reading and efficient written word recognition are essential prerequisites for achieving a good understanding of the text. According to their research, insufficient written word recognition has been shown to impact reading comprehension negatively. When individuals struggle to recognize words quickly and accurately, they expend more cognitive resources on the decoding process, leaving fewer cognitive resources available for higher-order tasks such as making inferences, integrating background knowledge, and maintaining coherence within the text. This reduced capacity for these essential comprehension processes can significantly hinder the overall understanding of the material being read (Perfetti, 1985). Rouweler et al. (2020) noted that text-reading fluency offers a more natural and ecological approach to assessing reading than word-reading fluency, as words are rarely read in isolation. For this reason, fluency at the paragraph and text levels is more critical in predicting reading comprehension, as it reflects a reader's ability to process larger chunks of information and maintain coherence across sentences. While word-level fluency is crucial for basic decoding, fluency at the paragraph and text levels enables better integration of ideas, supports inference-making, and enhances the ability to monitor and adjust comprehension in real-time (Brèthes et al., 2022). This higher-level fluency has been shown to correlate more strongly with overall reading comprehension skills, as it involves the complex cognitive processes needed to understand and retain the material being read. Another factor that can contribute to predicting both word reading and reading comprehension in students with dyslexia is vocabulary (van Setten et al., 2018). Nation and Snowling (2004) demonstrated that, in addition to phonological skills, oral language skills, including vocabulary, serve as both simultaneous and longitudinal predictors for word reading and reading comprehension. This relationship may be reciprocal, as decreased reading experience resulting from dyslexia can lead to lower vocabulary knowledge. For example, Snowling et al. (2007) revealed that advanced readers with dyslexia have lower vocabulary than those without dyslexia.

On the other hand, word decoding and recognition depend on phonological processing skills (Łockiewicz & Jaskulska, 2019). The primary phonological deficiency associated with dyslexia negatively impacts the specificity with which sounds are stored and recalled in words, as well as a person's ability to manipulate sounds in words and connect sounds to letters to read words (Adlof & Hogan, 2018). There is a wealth of evidence showing that children with dyslexia generally perform poorly on tasks related to phonology, such as phoneme awareness, word and non-word repetition, and word recall (Vellutino et al., 2004). Phonological awareness, which refers to the ability to recognize and manipulate sounds in spoken language, is considered a critical skill for reading development. However, phonological awareness is not the only factor influencing reading skills. Research has shown that rapid automated naming (RAN) and verbal short-term memory are also closely linked to reading fluency and comprehension. RAN, the ability to quickly name familiar objects, colors, or numbers, is a significant predictor of reading fluency because it reflects the speed and efficiency with which a person can access and process linguistic information. This skill is essential for fluent reading, as it enables readers to decode words and maintain a smooth reading flow efficiently.

However, there is an ongoing debate regarding whether RAN is an independent predictor of reading comprehension or if phonological processing skills, such as phoneme awareness, mediate its effects. Some researchers argue that RAN functions as a direct predictor of reading abilities, while others suggest that its impact may be primarily a result of its relationship with phonological processing (Krasowicz-Kupis, 2008).

Most of the current reading interventions described in the literature are short-term, classroom-based, and single-issue-oriented. However, according to Lovett et al. (2003), clinical interventions should holistically focus on all reading processes, including reading comprehension, mechanical reading, rapid automatic naming, phonological awareness, and fluency, with a particular emphasis on the development of correct decoding skills. In this context, the present study aims to examine the reading performance of children with dyslexia and those without and to reveal the level of differentiation using a holistic approach. The multisensory approach, an alternative for improving literacy skills in children with dyslexia and other reading difficulties, posits that individuals benefit from learning, processing, and development in a multisensory environment (Birsh, 2006; NEC, 2008). The core premise of the Multisensory Structured Language

Programme (MSP) is that most individuals learn more effectively by engaging multiple senses during the learning process. Correspondingly, it is believed that the simultaneous activation of numerous sensory pathways enhances learning in children with dyslexia (NEC, 2008). Numerous studies have been conducted to examine the effectiveness of the multisensory approach in strengthening the learning abilities of students with dyslexia and other learning difficulties (Mostafa & Ghani, 2016; Sarudin et al., 2019). In recent decades, educational technologies have advanced rapidly, and computer-based learning systems have shown potential in the field of special education. However, their effectiveness varies depending on the context and specific conditions (Lin et al., 2017). Research focusing on computer-based learning for students with dyslexia has explored how this method can improve reading and writing skills. For instance, a study by Eroğlu et al. (2020) found that a multisensory computer learning method improved the writing skills of individuals with dyslexia by strengthening their memory. Aside from Gharaibeh and Dukmak's (2021) study, there has been little research exploring the effects of computer-based multisensory learning approaches on reading skills in children with dyslexia.

METHODS

Study Design

In this study, a "quasi-experimental model with pretest-post-test control group," a subtype of authentic experimental designs, was employed. This model can be used to estimate causal relationships in cases where random sampling is not feasible due to ethical or practical reasons. In the present study, since random assignment of participants was not possible, this specific feature of the research design was utilized to reveal potential causal relationships (Büyüköztürk, 2011). Measurements were taken from both typical readers and students diagnosed with dyslexia before and after the experimental procedure, and the results were subsequently compared. The participants in the experimental group participated in a computer-based, multisensory training program for three hours per week over a six-week period. This training methodology, developed by the researchers, was explicitly designed to enhance reading performance by integrating Turkish reading materials. The duration of six weeks, with three hours of instruction per week, was informed by previous studies reporting measurable improvements in dyslexic learners following short-term, intensive interventions (e.g., Kast et al., 2007; Rello et al., 2015). These studies have shown that even short-term programs can yield gains in decoding and phonological awareness.

In this study's application of the MSP, the texts utilized were sourced from books recommended by the Turkish Ministry of National Education for primary school students. In selecting the texts used within the MSP, careful consideration was given to both the grade level and the learning profiles of the participating students with dyslexia. Texts were sourced from books officially recommended by the Turkish Ministry of National Education for primary school students. Two sets of texts were curated: one suitable for typical readers and another adapted explicitly for students with dyslexia. The selection process was informed by expert evaluations in the fields of special education and Turkish language instruction. Readability levels were determined using the Atesman Readability Formula (Ateşman, 1997), and only those texts with moderate readability levels were included in the program. Thematically, the texts covered common topics aligned with the Turkish primary curriculum, such as daily life, nature, family, and school settings. The average word count of the selected texts ranged between 120 and 180 words, ensuring that they were manageable within a single instructional session while still providing meaningful content exposure. This process ensured that all texts were pedagogically appropriate, cognitively accessible, and culturally relevant, aligning with national curriculum standards.

An application program has been designed in accordance with the research framework. The program was grounded in a multisensory approach that actively engaged students diagnosed with dyslexia through the simultaneous use of visual, auditory, kinaesthetic, and tactile modalities during Turkish reading and writing activities. Specifically, the visual modality was supported through enlarged fonts, high-contrast backgrounds, and customizable font colors, allowing students to compose text using their preferred colors. Auditory input was provided via text-to-speech features, enabling students to hear words as they read or typed them, thereby reinforcing phonological awareness. Kinaesthetic engagement was promoted by encouraging students to trace letters and syllables with their fingers on a touch-sensitive screen, enhancing motor memory. Tactile feedback was integrated through keyboard interactions and optional stylus tracing, enabling students to experience letter forms through movement and touch physically.

When composing responses to reading tasks, students typed in their chosen colors, with each word appearing on the screen accordingly. This personalized color-coding served as a visual anchor, strengthening word recognition and memory retention. The multisensory components were coherently integrated to maximize both student engagement and accessibility, in line with structured literacy principles and the Universal Design for Learning framework.

Furthermore, the program incorporated features of oral reading and auditory self-monitoring. As students read words aloud, their voices were recorded, enabling them to listen to and assess their pronunciation. While reviewing their recordings, students could compare their speech to the on-screen text, take notes on their reading style, and replay the recordings as needed to refine their pronunciation. This feedback loop promoted self-awareness and incremental improvement.

Overall, the program was designed to facilitate the activation of multiple sensory modalities within a computer-based learning environment, with particular emphasis on auditory, visual, kinesthetic, and tactile channels. As students encountered words, sentences, or complete texts on the screen, the program provided auditory output, supporting them in writing and repeating the words aloud. Voice commands and real-time feedback mechanisms further enabled students to monitor the correctness of their responses and adjust accordingly.

Participants

In Turkey, Guidance and Research Centres (GRCs) are responsible for organizing, delivering, coordinating, monitoring, and evaluating guidance, psychological counseling, and special education services at the provincial or district level. These centers consist of two central departments: the Guidance and Psychological Counselling Services department and the Special Education Services department (MoNE, 2020). The research group of the study consists of students who have been diagnosed with dyslexia by GRCs, as well as students who have not been diagnosed in this context. As a result, the research group includes 170 primary school children with dyslexia and 170 typical readers from the district of Antalya in the 2023-2024 academic year. The main reason for determining the research group size in this way is the number of students diagnosed with dyslexia in the Antalya region of Turkey in 2023 (MoNE, 2023). The typical readers were randomly selected from schools attended by students with dyslexia. In this way, the aim was to increase the similarity between the typical student group and the group diagnosed with dyslexia in terms of class level, environmental factors, and students' socioeconomic status.

In the process of identifying dyslexia, various tests are administered at GRCs. These include intelligence tests such as the Wechsler Intelligence Scale for Children-Revised (WISC-R), the Stanford-Binet Intelligence Scale, and the Leiter International Performance Scale (GRCs, 2020). Additionally, the Learning Disability Test developed by the Ministry of National Education is used to assess reading, writing, and mathematical skills, helping to identify students at risk of learning disabilities (MoNE, 2020). However, the authority to diagnose dyslexia lies with child psychiatrists in public hospitals. GRCs evaluate students who exhibit signs of dyslexia, administer relevant tests, and refer them to child psychiatrists for further evaluation and diagnosis. This process involves collaboration with the students' teachers and families to ensure a comprehensive assessment and guidance service (Özel, 2023).

Figure 1 shows that 34% (n=116) of the study group formed with girls, and 66% (n=224) of them were boys. In determining the grade level, typical students were selected in parallel with those of the dyslexic students. In this direction, 30% (n=102) of the students were from the 1st grade, 10% (n=34) from the 2nd, 24% (n=82) from the 3rd, and 36% (n=122) from the 4th grade. While 50% (n=170) of the students participating in the

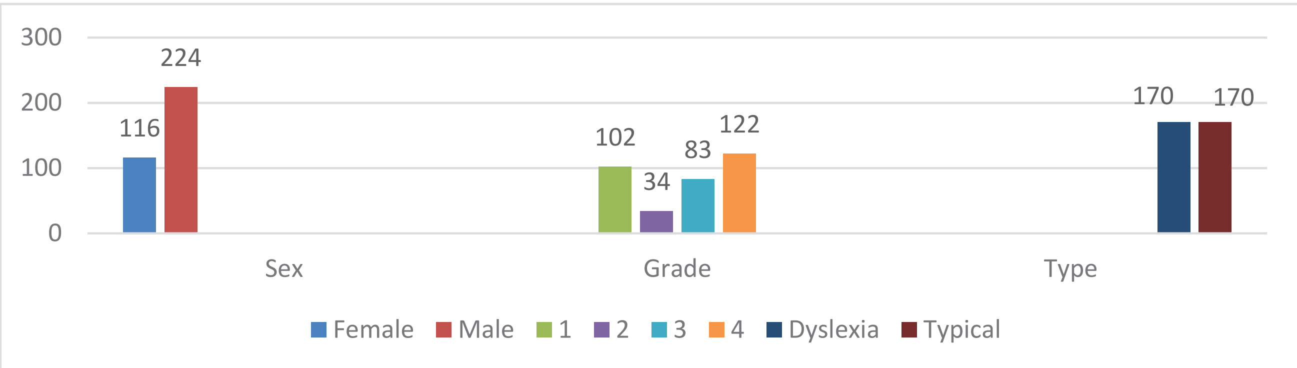

Figure 1. Demographic information on the study group

research were dyslexic students, the other half were typical readers. The unequal distribution of groups in terms of grade and sex, despite matching in terms of special needs/dyslexia diagnosis, is related to the random assignment of students who have already been diagnosed with dyslexia (Figure 1).

Data Collection Tool

Reading performances of students with and without dyslexia were examined in six subgroups: Reading words (meaningful and meaningless), reading speed, reading comprehension, mechanical reading, rapid automatic naming, and finally, phonological awareness.

The *Word Reading Knowledge Test (KOBİT)* is an individually administered assessment tool designed to evaluate the word reading skills of children aged 6 to 11, taking into account the grammatical and phonological features of the Turkish language (Babür et al., 2016).

The test consists of two subtests: one composed of real (meaningful) words and the other of pseudowords (nonsense words). Each subtest has two parallel forms (Forms A and B). The real-word subtest assesses the automatic recognition and decoding of familiar words, while the pseudoword subtest evaluates the child's phonetic decoding skills when confronted with unfamiliar word forms. During the administration, students are asked to read aloud as many words as possible from a list within 60 seconds.

There are 104 words in the meaningful word list. The nonsense word test, which is another subtest, measures the phonological coding knowledge that the student uses when reading unfamiliar words. This one consists of 63 non-words. In addition, this subtest has a parallel form with equivalent features. The student is asked to read the words in the list correctly, quickly, and aloud within a minute. The important thing here is the number of words read correctly in 1-minute.

KOBİT has demonstrated strong reliability and validity indicators. The internal consistency coefficients (Cronbach's alpha) ranged from .975 to .979 for the real-word subtest and from .930 to .946 for the pseudoword subtest. In terms of content validity, the test was developed based on Turkish word frequency lists and syllable structure, ensuring coverage of a wide range of lexical and phonological items. Construct validity was supported by high inter-correlations between the subtests and total scores (r = .90–.97). These findings provide robust evidence that KOBİT is a reliable and valid tool for assessing word reading efficiency and identifying potential reading difficulties among early readers in Turkish.

Reading Speed: This scale was designed by researchers to determine students' reading speed. The scale consists of a sample reading text and a total of five separate reading texts, each prepared according to a specific grade level (1st-4th grade). While preparing the reading texts, a text pool was created by selecting texts from the textbooks provided to students by the state that were suitable for the students' level. Target texts ideal for each grade level were developed by taking into account the opinions of three classroom teachers, two field expert academicians, and one language expert on the selected texts. While preparing the texts, the subject, sentence structure, word choice, sentence length, and letter size and shape were taken into consideration. During the application, the number of words correctly read by the child per minute, reading errors, and corrections were noted.

Reading Comprehension: In the study, narrative and informative texts suitable for each grade level were selected to determine students' reading comprehension levels. While selecting eight texts in total, the Ministry of Education's Turkish textbook was used as a reference, and a text pool was created. These determined texts were selected based on the opinions of three classroom teachers, two field expert academicians, and one language expert, resulting in two texts suitable for each grade level. The questions to be used to determine the reading comprehension levels of the students were prepared based on the reading comprehension achievements in the Turkish Curriculum. Multiple choice questions were used as the question type. An application was conducted with 200 students to analyze the prepared 20-question tests. In item analysis, the difficulty and discrimination indices of each item were calculated. Items with a discrimination index below .30 were excluded from the test. In addition to the discriminatory power of the items, whether there was a significant difference between the lower and upper 27% slices were determined by a t-test for independent groups. As a result, it was determined that eight items were not suitable for the student group, and after removing them from the test, 12 items remained.

Rapid Auto Naming: The Turkish adaptation of the Rapid Automatized Naming (RAN) (HOTIT) Test, developed by Wolf and Denckla (2005), was administered to a sample of 277 Turkish children aged 5 to 10 years. The test comprises four subtests: Objects, Colors, Numbers, and Letters, each designed to assess the speed and accuracy of naming familiar visual stimuli. Each subtest was presented on a separate card, with five symbols arranged in a shuffled sequence that was repeated 10 times. The HOTIT Pictures card features images of objects that are highly familiar to children. On the HOTIT Colors card, the colors "black, blue, green, red, yellow" are mixed; on the HOTIT Numbers card, the numbers "2, 4, 6, 7, 9" and on the HOTIT Letters card, the letters "b, k, m, s, t" are mixed, arranged in sequence and repeated ten times. In this test, the child is asked to recite the items on the card accurately and quickly, without skipping or missing any. In each subtest, the tester determines the child's performance in total minutes and seconds by keeping time with a stopwatch. During the application, any corrections and errors made by the child are noted. If the child pauses and appears unsure of what to do, the tester can instruct the child to start over again (Bakır & Babür, 2018).

Reliability analyses yielded strong results. Test-retest reliability coefficients, measured over a two-week interval with a subsample of 79 children, ranged from .85 to .95 across the subtests. Interrater reliability was also very high, with Pearson correlation coefficients ranging from .99 to 1.00, indicating excellent agreement between independent scorers. Validity evidence was provided through multiple approaches. Content validity was ensured through expert review and pilot testing to confirm the appropriateness, recognizability, and cultural relevance of the symbols used. Significant intercorrelations demonstrated construct validity among the subtests (r = .67–.83), strong negative correlations with chronological age (indicating developmental sensitivity), and significant negative correlations with oral reading fluency (r = –.55 to –.70), which supports the theoretical link between naming speed and reading ability.

Phonological Awareness: The phonological awareness test was developed by Karakelle (1998) to measure the level of phonological awareness. It consists of 4 sub-dimensions: rhyme recognition, phoneme deduction, phoneme combining, and syllable combining. The first sub-dimension of the phonological awareness test is rhyme recognition. Ten items were used for this measurement. Each item consists of 4 words, 1 of which is necessary, and the other three are selective. The subject was asked to recognize the word that rhymed with the first spoken word out of the last three words. All the words are real three-letter words. Phoneme decrement is the second sub-dimension of the test. For this measurement, 10 items were used. The words consist of 4 or 5-letter and 2-syllable words that have meaning even after the last letter is dropped in Turkish. The subject was asked to repeat the word said by the practitioner after omitting the last sound. The third sub-dimension of the test is combining phonemes. Ten items used for this measurement are real words with 2, 3, or 4 letters and 1 or 2 syllables. The students uttered the sounds that make up the words one by one, and the subject was asked to say which word was formed when these sounds were combined. The last sub-dimension is syllable consolidation. Ten items in this sub-dimension consist of real words with 4, 5, 6 letters, 2, and 3 syllables. The students said the syllables that make up the word one by one and asked to say which word was formed when these syllables were combined.

All tests were administered individually in a quiet, distraction-free room within the school premises, outside the regular classroom environment, to ensure controlled conditions. The assessments were conducted during regular school hours in April and May, with necessary permissions obtained from school administrations and classroom teachers. Each child participated in the study individually, and the full testing session lasted approximately 50 to 60 minutes per student. The tests were administered by a team of trained graduate-level researchers, all of whom received standardized training on the implementation and scoring procedures of each assessment tool before data collection. At the beginning of each session, participants were informed about the tasks in a language that was age appropriate. They were first given practice items, when necessary (especially for HOTIT and KOBIT), to ensure they were familiar with the format and stimuli. During timed tasks such as HOTIT, KOBIT, and the reading speed test, the examiner used a stopwatch to record the child's performance, noting all errors and corrections. For the RAN (HOTIT) and KOBİT tests, if a child had difficulty identifying the practice items (e.g., unfamiliarity with pictures, letters, or words), the corresponding subtest was not administered. In all other tasks, children were encouraged to perform to the best of their abilities without pressure.

Data Analysis

Before performing inferential statistics, the normality of the data was assessed using the Shapiro-Wilk test. For most variables, the assumption of normal distribution was met (e.g., *Rapid Auto-Naming - Mistakes (Typical)*: W = 0.996, p = .950; *Word Reading - Meaningful (Pre)*: W = 0.992, p = .505). One exception was found in the *Word Reading - Meaningless (Post)* scores of the dyslexia group (W = 0.980, p = .016), suggesting a minor deviation from normality.

However, given the robustness of the independent samples t-test in large samples (n = 170 per group), all analyses proceeded with parametric methods. Descriptive statistics (mean, standard deviation, minimum, maximum, and range) were reported for each variable. To compare the two independent groups (students with dyslexia and typical readers), independent samples t-tests were conducted across the following domains: *Rapid Automatic Naming* (pre- and post-tests), *Phonological Awareness* (six sub-dimensions), *Word Reading* (meaningful and meaningless, pre- and post-tests), *Reading Comprehension* (pre- and post-tests), *Reading Speed* (pre- and post-tests). In addition to statistical significance (p values), Cohen's d was calculated to assess the effect size of group differences, categorized as small (0.2), medium (0.5), and large (0.8). For instance, large to very large effects were observed in *Division into Syllables* (d = 1.94), *Word Reading–Meaningful* (d = 2.48), and *Reading Comprehension* (d = 2.35).

When multiple comparisons were made within the same domain (e.g., six subtests of phonological awareness), a Bonferroni correction was applied to reduce the risk of Type I error. The adjusted alpha level was set at $p < .0083$. Statistical significance was considered at $p < .05$, unless adjusted, and the results are presented in the following sections, along with full details on test statistics and effect sizes.

RESULTS

In this part of the research, the sub-problems were addressed by analyzing the findings and interpreting them.

Rapid Auto-Naming Skill

Before conducting the t-tests, the normality of the data was confirmed using the Shapiro-Wilk test, and no significant deviations were found (p > .05 for all comparisons). Additionally, Levene's Test for Equality of Variances indicated homogeneity of variances (p > .05). Therefore, parametric tests were deemed appropriate.

Table 1 presents the results of the independent samples t-test for the rapid automatic naming skill. A significant difference was observed in the number of mistakes during the pre-test between students with dyslexia (M = 1.90, SD = 2.69) and typical readers (M = 0.06, SD = 0.17), $t(9.09) = 16.00$, $p < .001$, $d = -0.97$, indicating a large effect size. No significant difference was found in the coding speed, $t(13.40) = 2.04$, $p = .06$, $d = 0.94$.

In the post-test, the difference in the number of mistakes was no longer significant, $t(8.07) = 11.00$, $p = .125$, $d = -0.10$. Similarly, there was no significant difference in coding speed, $t(15.30) = 2.82$, $p = .150$, $d = 0.84$. These findings suggest that the intervention may have had a positive impact on reducing error rates among students with dyslexia.

Phonological awareness skills

The assumption of normality was verified through the Shapiro-Wilk test (p> .05), and Levene's test confirmed the homogeneity of variances for all comparisons. Thus, independent samples t-tests were conducted across six phonological subskills. In Table 2, phonological awareness skills consisting of 6 sub-dimensions of students with dyslexia and students at typical reading levels were examined. Post-test results revealed no significant differences between groups in *Rhyme Recognition*, ($t(21.10)$ = 1.56, $p = .125$, $d = 0.50$) or *Phoneme Deletion*, ($t(21.80)$ = 2.80, $p = .058$, $d = 0.89$). However, significant differences emerged in: Phoneme Collation, $t(20) = 3.22$, $p = .003$ ($d = 1.02$); Syllable Collation, $t(19.50) = 3.33$, $p = .002$, ($d = 1.06$); Division into Phonemes, $t(19) = 4.69$, $p < .001$, ($d = 1.49$); Division into Syllables, $t(19) = 6.14$, $p < .001$, ($d = 1.94$). These results indicate that students with dyslexia demonstrated significantly lower performance than their typical peers in several core phonological awareness skills, with effect sizes ranging from large to very large.

Table 1. **T-test results for the rapid auto-naming scores of the study group**

Tests	Sub Test	Group	N	M	t	SD	p	Cohen's d
Pre experimental	Numberof Mistakes	Typical	170	0.06	16	9.09	0.001	-0.97
		Dyslexia	170	1.9				
	Coding Speed	Typical	170	41.65	2.04	13.4	.06	0.94
		Dyslexia	170	29.50				
Post-experimental	Numberof Mistakes	Typical	170	0.06	11	8.07	0.125	-0.1
		Dyslexia	170	0.08				
	Coding Speed	Typical	170	45.20	2.82	15.3	0.150	0.84
		Dyslexia	170	37.78				

Table 2. **Post-experimental T-test results of the study group's phonological awareness**

Variables	Sub Test	Group	N	M	t	SD	p	Cohen's *d*
Phonological Awareness	Rhyme Recognition	Typical	170	9.1	1.56	21.1	0.125	0.5
		Dyslexia	170	7.8				
	Phoneme Deletion	Typical	170	9.3	2.80	21.8	0.058	0.89
		Dyslexia	170	7.1				
	Phoneme Collation	Typical	170	9.7	3.22	20	0.003	1.02
		Dyslexia	170	7.6				
	Syllable Collation	Typical	170	9.8	3.33	19.5	0.002	1.06
		Dyslexia	170	7.2				
	Division into Phonemes	Typical	170	10	4.69	19	0.000	1.49
		Dyslexia	170	4.8				
	Division into Syllables	Typical	170	10	6.14	19	0.000	1.94
		Dyslexia	170	3.6				

Table 3. **T-test results of the study group's vocabulary reading skill scores**

Tests	Sub Test	Group	N	M	t	SD	p	Cohen's *d*
Pre experimental	Meaningful	Typical	170	89.8	7.83	38	0.000	2.48
		Dyslexia	170	57.8				
	Meaningless	Typical	170	79.9	5.58	38	0.000	1.77
		Dyslexia	170	54.2				
Post-experimental	Meaningful	Typical	170	90.3	4.4	20.3	0.075	0.58
		Dyslexia	170	81.6				
	Meaningless	Typical	170	81.1	3.76	15.4	0.576	0.31
		Dyslexia	170	76.6				

Reading Skills with Words (Meaningful and Meaningless)

When Table 3 is examined, it is seen that students with dyslexia differ significantly in word reading skills in both sub-dimensions compared to students at typical reading levels. All assumptions for t-tests were met. In the pre-test, typical readers significantly outperformed students with dyslexia in Reading Meaningful Words, $t(38) = 7.83$, $p < .001$, ($d = 2.48$); Reading Meaningless Words: $t(38) = 5.58$, $p < .001$, ($d = 1.77$). In the post-test, although the performance gap decreased, the differences were not statistically significant: Reading Meaningful Words, $t(20.30) = 4.40$, $p = .075$, ($d = 0.58$); Reading Meaningless Words, $t(15.40) = 3.76$, $p = .576$, ($d = 0.31$). These findings suggest a moderate reduction in group differences following the intervention, particularly in the reading of meaningful words.

Reading Comprehension

Table 4 presents Pre-test results that indicated a significant difference in reading comprehension scores, with typical readers ($M = 86$, $SD = 21.81$) outperforming students with dyslexia ($M=41$, $SD = 20.67$), $t(37.89) = 6.85$, $p< .001$, $d = 2.12$. In this case, it is possible to say that typical readers and students with dyslexia differ also in their reading comprehension skills. Post-test results did not show a significant difference between groups, $t(9.45) = 2.34$, $p = .145$, $d = 2.35$. Despite statistical insignificance, the very large effect size implies a continued practical gap between groups. This indicates a clear initial gap between the two groups in reading comprehension.

Reading Speed

According to Table 5, before the experimental procedure, a significant difference was observed between the arith-

Table 4. **T-test results of the study group's reading comprehension scores**

Tests	Group	N	M	t	SD	p	Cohen's *d*
Pre experimental	Typical	170	86	6.85	37.89	0.000	2.12
	Dyslexia	170	41				
Post experimental	Typical	170	76	2.34	9.45	0.145	2.35
	Dyslexia	170	62				

Table 5. **T-test results regarding the study group's reading speed scores**

Tests	Group	N	M	t	SD	p	Cohen's *d*
Pre experimental	Typical	170	76	5.88	38	0.000	1.9
	Dyslexia	170	30				
Post experimental	Typical	170	82	4.66	34	0.002	1.78
	Dyslexia	170	42				

metic mean of reading speed skills for typical students (M = 76) and that of students with dyslexia (M = 30) (t [37.89] = 6.85; $p < 0.05$). At pre-test, typical students read significantly faster ($M = 76$, $SD = 15.35$) than students with dyslexia ($M = 30$, $SD = 30.59$), $t(38) = 5.88$, $p < .001$, $d = 1.90$. This pattern remained at post-test, with typical readers ($M = 82$, $SD = 13.54$) again outperforming students with dyslexia ($M = 42$, $SD = 28.80$), $t(34) = 4.66$, $p = .002$, $d = 1.78$. These results reflect a persistent and substantial performance gap in reading speed.

DISCUSSION

The findings of this study reveal partial differences in the rapid automatic naming skills of dyslexic and typically developing children. The results showed that students with dyslexia made significantly more errors, although no significant difference was found in coding speed between the two groups. This suggests that the intervention, specifically the MSP, positively impacted the reduction of errors in dyslexic students; however, it did not influence their coding speed. These findings align with previous research (Lin et al., 2017; Guan et al., 2020), which shows that coding speed remained stable while error rates improved with targeted interventions.

In terms of phonological awareness, this study found no significant differences between the two groups in rhyme recognition and phoneme deletion sub-skills. However, the considerable difference in phoneme blending, syllable blending, and segmentation tasks suggests that the intervention had a limited impact on these skills in students with dyslexia. The fact that the gap in segmentation remained post-intervention (as seen in the Division of Phonemes and Division into Syllables) points to the need for more focused instructional methods to address these specific phonological challenges (Godfrey et al., 1981; Goswami, 2015). According to Zoubrinetzky et al. (2016), phonological awareness deficits in dyslexic children are marked by reduced sensitivity to phonemic boundary differences and increased sensitivity to allophonic variations. This discrepancy impairs the robustness of phonemic representations, thus hindering the acquisition of reading skills in children with dyslexia.

Significant differences were also found in word-reading abilities, particularly in the reading of both meaningful and meaningless words. While typical students outperformed dyslexic students in both categories, the intervention's ability to close this gap is notable. Following the intervention, no significant differences were found between the groups, indicating that the method employed successfully improved the word reading abilities of dyslexic students, both for meaningful and non-meaningful words. This result aligns with findings from Meyler and Breznitz (2005) and Jones et al. (2013), who observed improvements in word reading with targeted interventions, even among struggling readers. Kirkby et al. (2022) emphasize that proficient reading depends on the reader's ability to quickly and accurately identify orthographic patterns and their corresponding phonological matches. Dyslexic students, however, struggle with these processes, resulting in slower and less efficient word reading.

The findings of our study indicate that students diagnosed with dyslexia exhibited significant differences compared to typically developing readers in areas such as rapid automatized naming, phonological awareness, word reading, reading comprehension, and reading fluency—both before and after the intervention. However, post-intervention assessments revealed that these differences had considerably diminished, and in some subtests, they were no longer statistically significant. These outcomes suggest that the educational intervention had a positive impact on the reading skills of students with dyslexia.

When compared with the study conducted by Ransby and Lee Swanson (2003), both studies emphasize the influence of cognitive processes such as phonological processing, naming speed, and working memory on reading comprehension. However, Ransby and Lee Swanson (2003) found that adults with a childhood diagnosis of dyslexia continued to experience persistent difficulties in reading comprehension, which were associated not only with lower-level skills, such as phonological processing, but also with higher-order processes, including general knowledge, vocabulary, and listening comprehension.

In this respect, the intervention employed in our study may have contributed to improvements in both lower-level skills (e.g., phonological awareness, naming speed) and higher-order processes. Clarifying which specific components of the intervention led to these gains is essential. The MSP program integrated structured strategies, such as explicit phonics instruction, along with increased exposure to learning materials. Therefore, it remains unclear whether the observed improvements were primarily driven by phonics-based instruction that facilitated phonological awareness or by enhanced linguistic input provided through visual materials. Nevertheless, the significant improvements observed in phonological awareness—particularly in phoneme blending, syllable segmentation, and phoneme isolation—suggest that explicit phonics instruction played a critical role.

On the other hand, gains in word reading and reading fluency may have also been supported by the broader application of skills encouraged through the MSP program. According to Ransby and Lee Swanson (2003), difficulties in word recognition can constrain reading comprehension, as posited by the verbal efficiency theory (Perfetti, 1985). This theory posits that if lower-level processes are inefficient, more cognitive resources are consumed during decoding, resulting in fewer resources available for comprehension. Our findings appear to support this framework, as the improvements in phonological awareness and naming speed were accompanied by notable gains in reading comprehension among students with dyslexia. However, despite the post-intervention reduction in some statistical differences, the mean performance gap between dyslexic and typically developing students persisted across several measures. This suggests that, although the intervention was effective, specific cognitive and linguistic deficits may require more prolonged, intensive, and individualized support.

In conclusion, our study emphasizes the significance of components such as phonological awareness, naming speed, and explicit phonics instruction in improving the reading skills of students with dyslexia. When considered alongside the findings of Ransby and Lee Swanson (2003), it becomes evident that effective interventions must support not only phonological processing but also higher-order cognitive functions. Future research should aim to disentangle the specific contributions of each intervention component to different aspects of reading development.

Finally, the study addressed differences in reading speed, where typically developing students outperformed their dyslexic peers. The persistence of the reading speed gap after the intervention suggests that while the method improved accuracy and comprehension, it was less effective in increasing reading speed. This highlights the complexity of reading fluency development in dyslexic learners, as noted by Richlan (2019) and van Rijthoven et al. (2022). According to Perfetti's (2007) lexical quality hypothesis, reading fluency is the result of well-formed phonological, semantic, and orthographic representations. Dyslexic children, however, struggle with forming such high-quality representations due to phonological deficits, which in turn severely impair their reading speed and fluency.

The findings of this study suggest several practical implications for special educators and classroom practitioners. Firstly, educators should prioritize accuracy over speed in the early stages of intervention for students with dyslexia. The intervention significantly improved reading accuracy and comprehension but did not fully close the gap in reading speed. This aligns with the lexical quality hypothesis, which posits that accurate and well-formed phonological and orthographic representations are foundational to reading fluency. Consequently, instructional programs should focus on strengthening decoding skills and phonological awareness before emphasizing speed.

In terms of scaffolding strategies, multisensory instructional approaches should be systematically integrated into literacy instruction to enhance student learning. The results indicate that interventions incorporating visual (color coding, large fonts), auditory (text-to-speech, oral reading), kinaesthetic (tracing letters), and tactile (stylus feedback) modalities supported both phonological processing and self-monitoring. These strategies help learners form stronger phoneme–grapheme connections, enhance their involvement in working memory, and foster self-correction habits.

Moreover, educators can enhance reading comprehension in students with dyslexia by embedding oral feedback loops into reading activities. Allowing students to listen to their own recordings while following the text promotes metacognitive awareness and supports the development of reading fluency and self-evaluation skills. Finally, digital learning materials should be designed to respond across multiple sensory modalities, offering real-time feedback and reinforcing phonological and semantic links in reading. These insights underscore the necessity of individualized, explicit, and sustained instruction, particularly for students who continue to exhibit performance gaps after intervention.

ETHICAL APPROVAL STATEMENT

The ethical approval required for conducting this research was obtained from the Social and Humanities Ethics Committee of Alanya Alaaddin Keykubat University (Approval Number: E-70561447-050.04-186075; Document Date and Number: May 31, 2024). To avoid any ethical violations, informed consent was obtained from both the children and their parents through a written consent form.

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