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Eye tracking studies, a way to understand difficulties in reading processing

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Abstract

The aim of this study is to compare the features that characterise reading in Spanish, in dyslexic children and typical readers based on their eye movements, according to the different variables that characterise them: reading time, number and duration of fixations, amplitude, duration and speed of saccades, number of regressions and path length. The eye movements of 36 children aged 9-10 years (16 of whom were diagnosed with dyslexia) were studied while reading words and texts. The analysis showed significant differences in some of the variables studied. Dyslexic children perform a greater number of fixations, require more time to complete the reading task, perform shorter saccades and more regressions compared to typical readers. The average path length and the duration of fixations are similar in both groups.

Keywords: Eye tracking; dyslexia; learning disabilities; reading difficulties; educational needs.

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Los movimientos oculares, un camino para comprender las dificultades en el procesamiento de la lectura

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Resumen

El objetivo de este estudio consiste en comparar las características de la lectura en español en niños disléxicos y lectores neurotípicos en base a sus movimientos oculares, según las distintas variables que los caracterizan: tiempo de lectura, número y duración de fijaciones, amplitud, duración y velocidad de sacadas, número de regresiones y distancia recorrida. Para esto se estudiaron los movimientos oculares durante la lectura de palabras y textos de 36 niños de 9-10 años, 11 de los cuales fueron diagnosticados con dislexia. El análisis evidenció diferencias significativas en algunas de las variables estudiadas. Los niños disléxicos realizan un mayor número de fijaciones, requieren mayor tiempo para completar la lectura, realizan sacadas más cortas y más regresiones en comparación con lectores neurotípicos. La distancia media recorrida y la duración de las fijaciones es similar en ambos grupos.

Palabras clave: Seguimiento ocular; dislexia; trastornos de aprendizaje; dificultad lectora.

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INTRODUCTION

Dyslexia, a specific learning difficulty (SLD) in reading, affects a significant proportion of the population, estimated at between 5% and 10% (Carrillo-Gallego et al., 2011; Peterson & Pennington, 2012; Catts et al., 2024). People suffering therefrom experience persistent challenges in the process of learning to read. It is crucial to detect dyslexia at early stages so that appropriate educational strategies can be implemented from the initial school years. It is widely recognised that reading ability is the most essential instrumental skill in the school environment, becoming a fundamental tool that facilitates other learning processes. This skill transcends the mere acquisition of reading, serving as a means for acquiring knowledge.

The International Dyslexia Association defines dyslexia as a specific learning difficulty (SLD) likely of neurobiological origin, characterised by difficulties in accurate and/or fluent word recognition, as well as in decoding and spelling (World Health Organization, 1993; American Psychiatric Association, 2013). These difficulties are usually the result of a deficit in the phonological component of language. They are unexpected in relation to other cognitive abilities that develop typically with appropriate schooling. As secondary consequences of these difficulties, problems in reading comprehension and reduced reading experience may arise, potentially impacting vocabulary growth and the acquisition of new knowledge.

Dyslexia is considered the most common learning disorder (Snowling, 2001) and is characterised by difficulty in reading and spelling words despite adequate intellectual resources and learning opportunities (Lyon et al., 2003). Liberman's research (1995) indicated that reading, unlike spoken language, does not develop naturally or universally, and unexpected difficulties may emerge despite prior controlled conditions.

The latest research on the definition of dyslexia (Protopapas, 2019; Catts et al., 2024) emphasises the idea of persistent reading difficulties, offering its most recent definition: a persistent and unexpected difficulty in developing word reading skills, given age and experience (Parrila & Protopapas, 2017).

The development of reading skills takes several years, beginning when children learn the initial steps of decoding between the ages of 4 and 7, depending on environmental characteristics and the emerging language. A key factor in this process is the type of stimulation promoted in school, which varies across different countries and educational systems. Learning phoneme-grapheme correspondence rules takes around two years, depending on the orthographic complexities unique to each language (Seymour et al., 2003; Ziegler & Goswami, 2006). However, reading speed continues to progress throughout various school stages, ultimately achieving a rate of 200 to 300 words per minute when reading continuous text. This gradual automatisation of reading prevents interference with more complex processes, such as reading comprehension (Megherbi et al., 2018).

Spanish is identified as a transparent language, a feature that plays a key role in learning written language. Seymour et al. (2003) classified European orthographic systems in a cross-linguistic study, distinguishing syllabic complexity and the balance of opacity and transparency in the decoding process. This study became a key foundation for the LEE test (Reading and Writing in Spanish) (Defior et al., 2006), from which the Word Reading, Pseudoword Reading, and Text Comprehension tests were utilised.

In the study by Seymour and collaborators (2003), Spanish is described as a transparent language, as there is a one-to-one correspondence between phonemes and graphemes, with some exceptions that are more pronounced in Rioplatense Spanish, such as the phonological representation of "c," "s," or "z," which are recognised by the same phoneme, and the presence of numerous homophones. This transparency facilitates the acquisition of written language. In contrast, in opaque orthographies with more complex syllables, learning to read would be more challenging. Dyslexia in Spanish is also influenced by the orthographic transparency of the language, with reading speed being the key distinguishing factor, as accuracy is easier to acquire (Defior, 2020; Wolf et al., 2024).

Both decoding and comprehension are fundamental components of reading and are intrinsically related; if decoding is inadequate, the purpose of reading is not achieved (Hoover & Tunmer, 2020;

Abusamra et al., 2021), as the ultimate goal is comprehension. Therefore, reading constitutes a complex process requiring the integration and coordination of various perceptual (visual, auditory, and phonological), attentional, motor, linguistic, and cognitive processes, all operating simultaneously at a remarkable speed. Each of these processes must function precisely and swiftly before being integrated within milliseconds to enable the reading of a single word.

From a visual perspective, reading involves extracting information from text presented as an image. Due to the characteristics of the visual system, the text can only be processed in fragments, achieved through eye movements (hereafter EMs) that position each fragment of text within the fovea, the part of the eyes with the highest resolution. Several motor areas of the brain are required to execute the eye movement from one word to the next. The brain breaks down the image into pieces that are analysed as they pass through the angular gyrus, Wernicke's area, and various other areas of the brain, eventually linking it to a word or part of a word, thereby giving meaning to the stimulus.

THEORETICAL FRAMEWORK

The study of eye movements during reading has a long history. In recent decades, researchers in this field have focused on characterising and modelling the different mechanisms involved in the reading process. Two basic principles govern reading dynamics: where to look and when to move the eyes to the next target. In attempting to explain these, a set of metrics has been established to describe the reading process in great detail (Rayner, 2009; Engbert et al., 2005).

When reading, the reader makes very rapid movements (called saccades) that shift the gaze forward along the text (progressive saccades) or backwards (regressions), followed by moments of relative stability (fixations). The study and detection of eye movements began in the late 19th century, using observational methods with mirrors (Yarbus, 1967). Decades of technological advances have enabled clinical recording of eye movements, which can now be easily and precisely recorded with devices known as eye trackers. Today, many systems use infrared light reflected from the eyes, captured by a video camera that records eye movements while the subject looks at a series of stimuli, without requiring physical contact. The corneal reflection of the light is measured relative to the location of the pupil centre, generating a large amount of data from which clinically useful information can be extracted. These data can be analysed using statistical mathematical methods or modelling from a physical perspective. In the first case, several metrics are defined, such as the number of fixations, fixation duration and location, saccade amplitude, etc. (Duchowski, 2017). In the second case, the physical aspects of eye movements are studied, considering the system formed by the oculomotor globe and the muscles involved in eye movement (Specht et al., 2017; Bouzat et al., 2018, Del-Punta et al., 2019; Frapiccini et al., 2020).The study of these eye movements has allowed for the characterisation of reader groups with similar characteristics: children beginning to learn, adolescents or adults without specific difficulties, older adults, and dyslexic individuals, among others. According to Escudero et al. (2016), saccadic movements are rapid movements that enable the eyes to shift from one fixation point to another, between which information is recognised and processed. In silent reading, they typically span 7 to 9 characters, although this can vary depending on the text being read, and their duration ranges from 20 to 40 milliseconds. During saccadic movements, sensitivity to visual information is reduced, recognised as a mechanism of saccadic suppression related to inhibition processes. However, it has been shown that lexical processing is not suppressed (Irwin, 1998).

Saccadic movements alternate with fixation periods, allowing the reader to jump from one point to another quickly and discontinuously (Klein & Ettinger, 2019). In reading, the gaze focuses on a specific text fragment while visual word recognition occurs, then jumps to the next fragment or, occasionally, moves backwards to reread some part of the text, a movement known as a regression. Regressions are small leftward saccades (in Spanish) that occur when a person needs to reread a section of the text. They tend to happen when a saccade is too fast or encompasses more information than the reader can perceive or process. Approximately 10-15% of all saccades are regressions (Holmqvist et al., 2011).

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Fixations refer to the movements that occur when the eye is relatively still and focuses on a particular target. Their duration is associated with the task at hand, mainly the cognitive demand required by the task. Generally, fixations last between 150 and 300 milliseconds. In reading, fixation duration averages around 225 ms for silent reading and about 275 ms for reading aloud (Rayner, 1998). Fixations account for approximately 90% of reading time, during which the reader focuses their fovea on a text fragment where information is recorded and analysed. During this period, the eyes exhibit only brief movements, remaining nearly immobile while visual word analysis and underlying cognitive processes occur.

Furthermore, fixations depend on the type of text (the more challenging, the more fixations occur), the reader (skilled readers make fewer, shorter fixations and regress less), the type of words (for example, content words attract more fixations than functional words), and so on. Generally, content words receive more fixations than functional words. Content words are fixated about 85% of the time, while functional words are fixated only 35% of the time because they tend to be shorter and more frequent (Carpenter & Just, 1983).

The characteristics of children's eye movements differ from those of adults. Eye movements seem to reach adult levels around the age of 10-12 (Blythe & Joseph, 2011). Preschool-aged children often display small saccades and drifts during fixation. Their latencies or durations tend to be longer and less precise, for example, when scanning a scene (Kowler & Martins, 1982).

The number of fixations during reading, their duration, and the percentage of regressions differ depending on whether the reader is a child learning to read, a skilled adult reader, an individual over 65, a deaf person, or a person with dyslexia. Young children learning to read must exert significant effort to recognise the words they see, resulting in a smaller perceptual span (the number of characters between saccades). Additionally, children make more regressions because they are uncertain about what they are processing, as their linguistic and lexical knowledge is still developing (Leinenger & Rayner, 2017).

Various studies have also concluded that skilled readers' eye movements are under direct cognitive control (Rayner, 1978; 1998). When a reader fixates, examining the duration of fixation and the type of words they skip or regress to provides valuable information for analysing the underlying processes in reading as they occur, in real-time. This process develops in parallel with reading comprehension.

Hyönä and Olson (1995) reported in their research that not only is word length important in analysing the reading process, but prior knowledge of the word also aids in accurate and fluent recognition and decoding. They observed typical behaviour in children with dyslexia, who generally made a higher number of fixations, longer fixation durations, and more regressions on low-frequency words compared to familiar or high-frequency words, suggesting that eye movements reflect their linguistic processing difficulties.

Similarly, Pirozzolo & Rayner (1979, 1988) found that if children with dyslexia are provided with a text suited to their reading level, their eye movement pattern was similar to that of neurotypical readers of the same age.

Rello & Ballesteros (2015) and Ponce de León & Cuadro (2017) agree in noting differences between the eye movements of children with dyslexia and neurotypical readers, emphasising that eye movements are not the cause of reading difficulties, but rather a reflection of underlying processes. They observed that dyslexic children, like those learning to read, tend to make shorter saccadic movements, more fixations, longer fixation durations, and show differences in the number of regressions.

OBJETIVES

In this study, we explore the contribution of eye tracking to the study of dyslexia in children. The aim is to identify variables derived from eye movement recordings that could serve, alongside existing tools, as a diagnostic aid for dyslexia. Eye movements are physiological metrics that could help differentiate between a poor reader and a reader with dyslexia, thus providing early guidance for the child in developing compensatory strategies for this difficulty.

METHOD

Participants

The sample under analysis was classified into two groups. One group consisted of 25 children aged 9-10 who are in the 4th grade of Primary Education at a school of middle socioeconomic status (SES) in the Greater Buenos Aires Metropolitan Area (AMBA, Argentina), representing the typical readers group. Additionally, 11 children with dyslexia, diagnosed by educational psychologists and residing in the same city area, were evaluated. Parents of the participants signed an informed consent, and the children provided assent, with the necessary authorisations from their schools. All participants spoke Spanish as their mother tongue.

Procedure

The evaluation procedure involved children reading aloud a list of words and a text from the LEE test, appropriate for their age. The 25 4th-grade children were assessed in the school setting, while children with dyslexia were evaluated in the clinical setting where they had been diagnosed and were receiving weekly treatment. No exclusion criteria were applied to either group.

The text was presented digitally on the PSIMESH web platform (www.psimesh.com), developed and managed by the Integrated Centre for Applied Neurosciences (CINA) in Bahía Blanca. This platform allows the stimulus to be displayed to the research participant, records the audio, and tracks eye movements during text reading.

The participating children were shown the text on a computer screen, in black letters on a white background. Evaluation was individual and conducted on a turn-by-turn basis. Prior to starting the reading, each child completed eye-tracker calibration, which involved looking fixedly at a series of points that appeared consecutively until they disappeared. Once calibration was complete, the child read the text aloud. During the process, the sensor illuminates the subject with infrared light and records an image that is analysed in real time, providing the system with gaze position information on the screen over time.

The recorded data consists of time series indicating the horizontal and vertical coordinates of the gaze on the screen at each moment, at a frequency specific to the device, 90 Hz in this case. These data are recorded and partially processed through the digital platform.

Materials

All children read aloud the word list from the Word Reading test and the text *Los delfines* from the Reading Comprehension test in the LEE (Defior et al., 2006), displayed on a 17-inch monitor. Figure 1a shows the list comprising 42 words selected based on frequency, length, and type of orthographic complexity (26 complex words, 8 simple words, and 8 words with consonant clusters). Figure 1b shows the text *Los delfines* from the Reading Comprehension test. This is an expository text of medium complexity, containing 86 words. The reading was done aloud.

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Figure 1

Words list from the LEE test (Defior et al., 2006). (b) Text Los delfines

(a)

chiste	péndulo	dedal	pelaje
duquesa	nuez	prensa	fiel
hundido	aduana	guiño	mantel
cisne	tableta	hiena	asfalto
gitano	anguila	hamaca	jungla
pompa	honda	gentil	pupitre
empeño	flan	rima	fachada
balsa	astronauta	cruel	repisa
payaso	animó	dependiente	faro
entretenimiento	mástil	pavo	fijó
mandamiento	derrota		

(b)

Los delfines habitan en los mares y los océanos; también en algunos ríos.
Prefieren nadar cerca de la superficie del agua y se desplazan velozmente, dando enormes saltos.
Son animales mamíferos, pueden medir hasta dos metros, poseen una gran inteligencia y tienen un oído muy desarrollado.
Viven en grupos. Cuando alguno de ellos se encuentra en peligro, los demás se acercan para ayudarlo.
Algunos marineros cuentan que vieron cómo los delfines ayudaron a personas que estaban en situaciones peligrosas en el agua. Son muy solidarios.

RESULTS

Visual Exploration of Visual Patterns

Before analysing the data obtained from the groups of dyslexic and typical children, some observational aspects regarding the visual patterns of children performing reading tasks, both word lists and text, are presented. For this purpose, eye movement (EM) records from two specific subjects (S1 and S2), considered representative of each studied group, were selected. S1 belongs to the group of typical readers, while S2 is part of the group of children with dyslexia.

Figure 2

Screenshot showing fixations during reading of the word list from the LEE test (Defior et al., 2006)

a) Record of S1

b) Record of S2

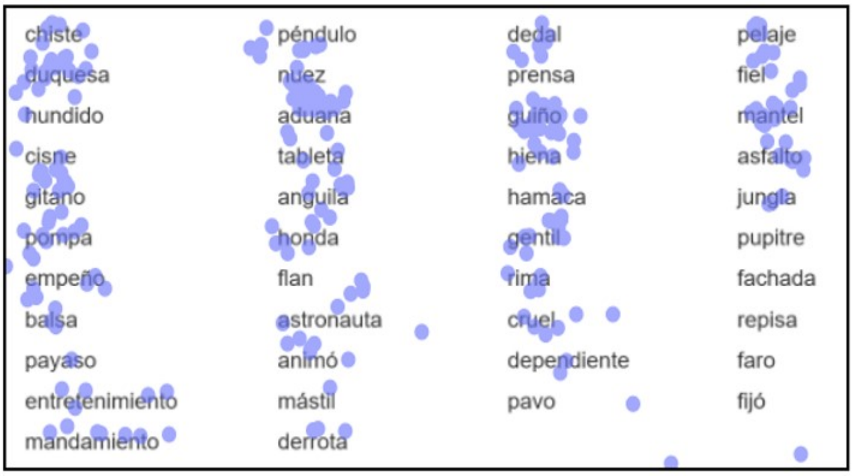

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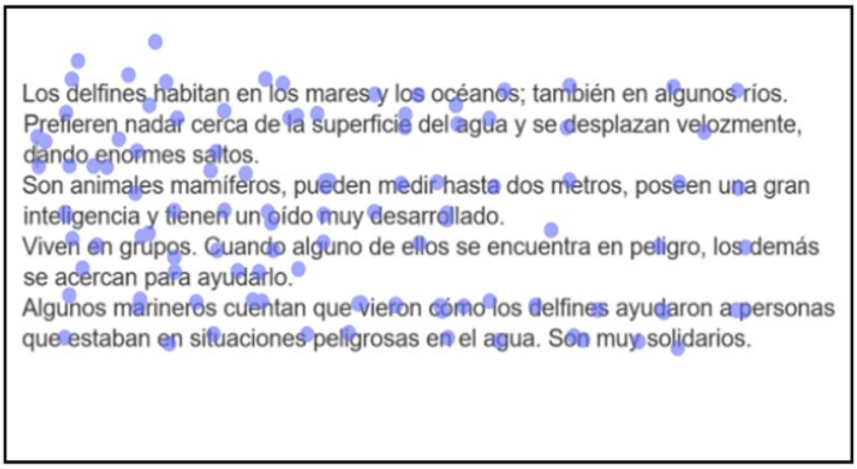
Figure 3

Screenshot showing fixations during reading of the text Los delfines*, from the LEE test (Defior et al., 2006)*

a) Record of S1



b) Record of S2

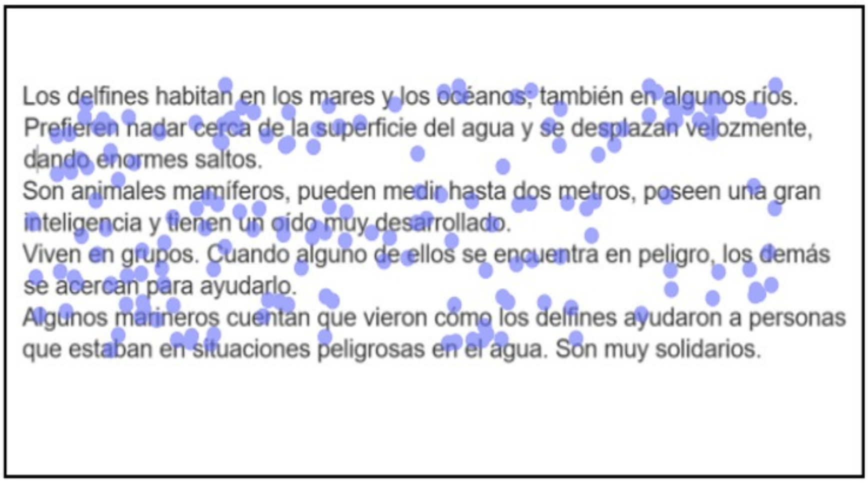
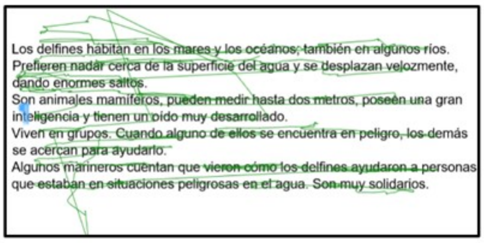


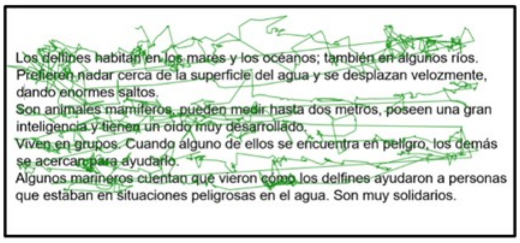
Figure 4

Eye movement tracking records of the two readers during reading of the assigned text

a) Record of S1



b) Record of S2



For S1, in reading the word list, an efficient reading pattern is observed, with the child making a fixation in the centre of the word or slightly to the left in the so-called preferred viewing location (Rayner, 1978). This behaviour is maintained throughout almost the entire word list, flexibly expanding the number of characters that can be recognised in a single fixation. More than one fixation is only observed on the words “dependiente” (dependent) or “fachada” (facade), which are longer or less familiar words. In the text reading, some words are also fixated on more than once, while others are skipped (Blythe et al., 2011), mainly if they are short or frequent and are processed parafoveally.

For S2, a greater number of fixations is observed as they require more time to process each word, segmenting each word into small subunits that need to be sequentially reassembled. Reduced efficiency of lexical and sublexical processing is seen in each fixation. During text reading, greater difficulties in decoding are evident. Many of the movements are random and inefficient, not always directed conceptually. This could indicate a focus on decoding rather than comprehension.

Statistical Data Analysis

The results obtained from each representative sample group, typical readers and those diagnosed with dyslexia, are presented below. Table 1 shows the medians for different variables analysed during reading of the text *Los delfines*. These parameters were selected and analysed as there is no evidence that the studied values follow a Gaussian distribution that would justify using mean values.

The obtained values for the defined variables (total reading time, number and duration of fixations, duration, and amplitude of saccades) reveal differences and similarities between the two studied population samples. A difference is observed in the median number of fixations and total reading time, supported by results from a Mann-Whitney U test ($p<0.05$ for both variables) and a power analysis, which produced power values of 0.93 for reading time and 0.92 for the number of fixations (Noether, 1987). We conclude that these variables are sensitive and valuable indicators for categorising the groups. The median duration of fixations does not vary between typical children and those diagnosed with dyslexia. However, a statistically significant difference in the number of fixations was observed, which accounts for the difference found in total reading time.

Table 1

Statistical description of various variables characterising fixations and saccades in the two studied population samples during reading of the text Los delfines

Fixations and Saccades		Neurotypicals	Dyslexics
	Characteristic	Median	Median
	Total ReadingTime (s)	51.9	90.8
Fixations	Number	137	207
	Duration (ms)	222	223
Saccades	Duration (ms)	55	52
	Amplitude (um)	1.06	0.54

In figure 5, the number of fixations is shown in relation to the median fixation duration for each participant, with values for both groups varying within the same time ranges..

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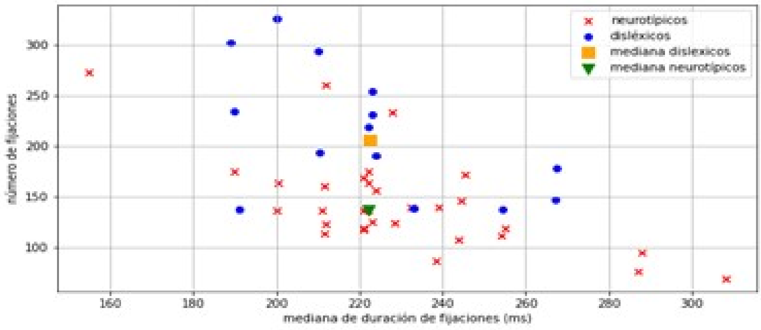
Figure 5

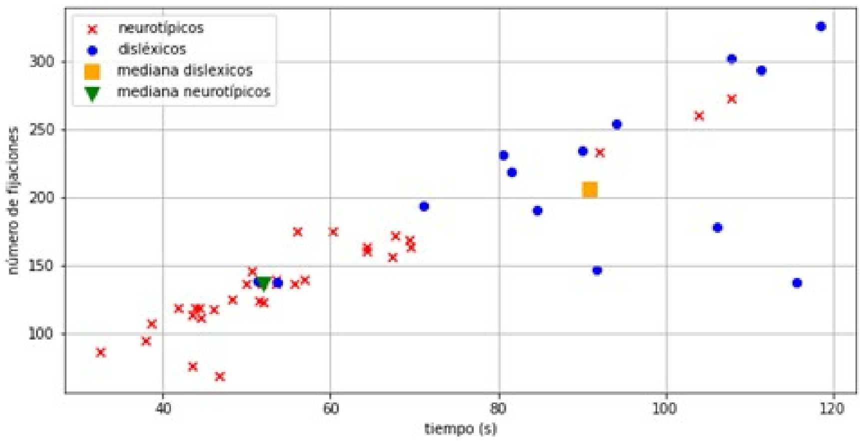
Representation of the number of fixations and their median duration for each child in the typical readers and dyslexic groups, along with the median value for each group



Given the similarity in fixation duration, we can conclude that the difference in time required for the reading task is directly related to the number of fixations. We found that these variables have a strong positive linear correlation (Spearman correlation coefficient r=0.91). This is shown in figure 6, where, for each individual, reading time (horizontal axis) and number of fixations (vertical axis) are plotted. A clear grouping of typical readers can be observed, with fewer than 200 fixations and reading times generally under 70 seconds. Conversely, dyslexic children have reading times over 70 seconds and generally make more than 200 fixations.

Figure 6

Representation of the number of fixations and total reading time for each child in the typical and dyslexic groups, along with the median value for each group



In figure 6, three children who are not diagnosed with dyslexia but whose values for number of fixations and reading time fall within the dyslexic range are also evident.

The analysis of saccadic movement characteristics indicates that there is no significant difference in saccade duration between the groups; however, the median saccade amplitude is approximately half in dyslexic children compared to neurotypical readers ($p<0.05$ in the Mann-Whitney U test). These saccades may be forward or backward. Table 2 provides a characterisation of each.

Table 2

Statistical values of variables characterising forward and backward saccadic movements over the text Los delfines*, by study group*

Forwards and Backwards		Neurotypicals	Dyslexics
	Characteristic	Mediana	Mediana
FORWARDS	Duration (ms)	55	54
	Amplitude (um)	1.10	0.56
	Average Speed	0.017	0.010
	Maximun Speed	0.027	0.015
BACKWARDS	Duration (ms)	54	49
	Amplitude (um)	0.99	0.55
	Average Speed	0.017	0.010
	Maximun Speed	0.028	0.017
	Total Proportion %	31 (4)	30 (4)

The results in table 2 show that the differences between both groups for amplitude, average speed, and maximum speed that characterise saccadic movements are equivalent regardless of whether the movement is forward or backward. This means the median for dyslexic children indicates shorter and slower saccadic movements compared to those of typical children. Another important result is that the percentage of regressions in the total saccadic movements is equivalent in both groups, resulting in a higher number in the dyslexic group.

DISCUSSION

The general objective of this study was to investigate the reading characteristics of primary school children in fourth grade who have already mastered the process of written language acquisition and achieved a certain level of automation, comparing them to the reading patterns exhibited by children with dyslexia of the same age through the study of their eye movements (EM).

The findings of this study are consistent with expected results in terms of speed and accuracy. Children with dyslexia read more slowly, make more errors, and display syllabification and hesitations compared to their controls. Regarding EM, the results align with previous research indicating that readers with difficulties make more fixations, shorter and slower saccades, more regressions, and take more time to reread the text than neurotypical readers (Ashby et al., 2005; Premeti et al., 2022). Additionally, children with dyslexia were observed to experience greater difficulty in word processing, considering the effects of length, frequency, and orthographic complexity (Ashby et al., 2005; Haenggi & Perfetti, 1994), suggesting they are less efficient in lexical processing during each fixation (Schilling et al., 1998). This characterisation aligns with the observational description of the EMs of children S1 and S2, who were taken as representatives of each group.

This study observed differences in word recognition across both groups, a necessary step toward understanding the text being read. Skilled readers scanned the text flexibly, adjusting saccades to the length and complexity of the words being read; for longer words, they made longer saccades, processing more characters and demonstrating an advantage in word recognition. The EMs of child S1 during reading illustrate this characterisation. For dyslexic readers, EMs were characterised by analysing smaller units within each word, typically fragmenting 8 to 10 characters into three or four segments, depending on the word's complexity, indicating a prevailing use of sublexical or phonological processing, as observed in other studies (De-Luca et al., 2002). The description of the EMs of child S2 reflects these findings.

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When analysing the results of the typical readers group, three children (figure 6) had not been identified by their teachers as having significant reading difficulties or diagnosed with dyslexia. Their values for fixation count and reading time were similar and within the range of the dyslexic group. This information could be useful in educational settings, enabling the early identification of children who may require further assessment of their reading performance. Likewise, this data could be of interest to educational psychologists, allowing them to consider the possibility of more precise evaluations and timely intervention in children who had not previously been diagnosed.

When comparing the reading patterns of the two children studied, we observe that S1 processes not only information within the fovea but also attends to other information that appears in the parafoveal region, shifting focus to the next target word while still processing previous information with regard to orthographic, phonological, and semantic aspects (Rayner, 1998; 2009; Schotter et al., 2015; Leinenger & Rayner, 2017), and regressions mainly target content words.

Less skilled readers have a smaller visual perceptual span than more skilled readers, needing to make several fixations on a word (Rayner et al., 2010). Moreover, these readers do not engage sufficiently in parafoveal preprocessing (Veldre & Andrews, 2014), which is essential for efficient and rapid information processing. Longer regressions, such as moving back more than 10 characters or to another line, generally occur when comprehension fails. Readers with difficulties must often backtrack several times (Murray & Kenedy, 1988).

Frequent regressions may also be explained by the dyslexic reader's need to reread the text to recognise words and access meaning due to their decoding challenges.

De-Luca and colleagues (2002), comparing EMs in dyslexic and typical readers when reading words and pseudowords, concluded that dyslexic readers process words similarly to how typical readers process pseudowords, adopting a sublexical grapheme-phoneme processing approach that overlooks the lexical value of the word. This results in slow, sequential reading that prioritises grapheme-phoneme decoding and processing of small word units, lacking a more efficient global processing that would increase speed. This aligns with dual-route model researchers' proposals, suggesting that dyslexic readers experience weaknesses in both phonological and lexical processing (Castles & Coltheart, 1993; Cuetos-Vega, 2010). Skilled readers have specific lexical representations of numerous words, enabling quick and automatic identification, allowing faster reading and efficient comprehension.

Successful reading instruction should assist children in improving their word recognition system and language processing, rather than focusing solely on EM mechanisms, which should become more adult-like as a result of improved linguistic processing. EMs become more regular as linguistic processing improves (Leinenger & Rayner, 2017).

These results are consistent with previous studies (Fonseca et al., 2009) demonstrating a significant positive relationship between word recognition task performance and reading comprehension outcomes, particularly in the general population, as many studies have noted (Perfetti, 2007). Children who efficiently use lexical processing for word recognition typically achieve adequate text comprehension. In the early primary school years, there seems to be a dependency between these components, suggesting that word recognition tasks may predict reading comprehension performance in children from Year 1 to Year 4. Decoding plays a prominent role in the early years, helping children expand their orthographic vocabulary and thus their word recognition efficiency (Savage, 2006).

CONCLUSIONS

From the 1950s to the present, dyslexia, initially referred to as “word blindness,” has been the subject of numerous research studies and subsequent publications, as Helland (2022) has detailed. However, even today, some children progress through school without a proper diagnosis and intervention.

Our research group is motivated not only by the academic study of dyslexia but also by the quest to develop tools that can contribute concrete information to existing diagnostic methods. Starting from this objective, and given the relatively low number of publications in Spanish compared to other languages, we conducted this study on dyslexia using eye movement recording. In this initial study, data obtained from measurements were processed using descriptive statistics of various variables derived from eye movement records in this sample. Although our study has some limitations, such as the lack of preliminary assessments of participants' visual state or vocabulary, we have observed that some reading process characteristics differ between children with dyslexia and neurotypical children. These differences align with findings from previous studies. Typical readers make fewer fixations and saccades of greater amplitude (both forward and backward) than dyslexic children, although there is no difference in movement duration between the two groups. Another distinguishing feature between the groups is the number of regressions, with the dyslexic group showing a higher count.

In conclusion, this study identified eye movement characteristics that allow differentiation of the decoding process in reading a Spanish text between a group of children diagnosed with dyslexia and a neurotypical group. Moreover, it is evident that the information obtained through eye-tracking is valuable not only for advancing the study of dyslexia but also, using appropriate software and eye-tracking equipment, can be accessible and useful in educational and clinical settings.

Aligned with these objectives, some authors of this work have conducted studies using tools from statistical physics and machine learning that enable the separate identification of the two groups. Specifically, by calculating the quantities of complexity and entropy based on data from all subjects, the methodology separates dyslexic and neurotypical groups according to the characteristics of their eye movements.

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AUTHOR CONTRIBUTIONS

Karina-Viviana Rodríguez: Project administration; Formal analysis; Conceptualisation; Writing - original draft; Writing - review and editing; Investigation; Methodology; Resources; Software; Supervision; Validation; Visualisation.

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