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Visual attention and phonological processing in children with developmental language disorder

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Introduction: Developmental Language Disorder (DLD) is a neurobiological condition characterized by insufficient language and communication development, with no underlying physical, sensory, or cognitive explanations. A prominent feature among children with DLD is their struggle with phonological processing, a pivotal skill for later reading proficiency. Recent research suggests that children with DLD may also exhibit impairments in various non-linguistic cognitive abilities, including memory, attention, and perception. Of particular importance is visual attention, which plays a critical role in integrating visual perceptual information with diverse cognitive and linguistic processes.

Objective: To characterize visual attention during phonological processing tasks in Colombian children with DLD.

Methodology: This study employed a cross-sectional descriptive experimental design involving 20 children diagnosed with Developmental Language Disorder (DLD) and 20 children without language difficulties. All participants underwent language, vocabulary, and phonological awareness tests. Additionally, an experimental task utilizing the eye-tracking method was designed and administered to measure phonological processing with phonological and lexical distractors.

Results: Children with DLD exhibited diminished performance on phonological awareness tasks, as evidenced by their lower scores. This was further supported by the experimental phonological processing task, where an interference effect was observed in the presence of lexical distractors for word recognition, but not with phonological distractors.

Conclusion: Children with DLD demonstrated deficiencies in both phonological awareness and visual attention skills during linguistic and phonological processing tasks. They also exhibit reduced sensitivity in identifying phonological relations such as rhyme. The study discusses these findings along with their clinical implications, emphasizing the importance of assessing online processing abilities in children with DLD and considering the influence of other cognitive abilities on their linguistic performance.

KEYWORDS

developmental language disorder, phonological awareness, visual attention, eyetracking, phonological processing

1 Introduction

Developmental Language Disorder (DLD) is a neurodevelopmental disorder that begins in early childhood and often persists into adulthood. Children with DLD have significant difficulties learning, understanding, and using spoken language. DLD is one of the most common neurodevelopmental disorders, with an approximate prevalence of 7% (Norbury et al., 2016).

DLD is characterized by poor language development without a physical, sensory, or cognitive explanation (Leonard, 2014). The main difficulties of this pathology are found in the language component, coexisting with alterations in the phonological domain (Catts and Kamhi, 2005) and in the semantic lexical organization (Sheng and McGregor, 2010).

Although the primary and almost exclusive difficulty in DLD is specifically linguistic in nature, recent studies have found that children with this diagnosis also have non-linguistic problems, such as difficulties in rhythmic and musical processing (Guarnera et al., 2013; Przybylski et al., 2013), executive functioning (Pauls and Archibald, 2016), behavior (Özcebeet et al., 2020), and deficits in visual-attentional skills (Dispaldro et al., 2013). Although the nature of DLD is still unclear, Ullman and Pierpont's (2005) thesis on procedural deficits in DLD opens an interesting avenue of research, as it hypothesizes an abnormal development of interconnected brain structures involved in learning and executing motor and cognitive skills, which could explain the variability of performance in children with DLD in different cognitive functions beyond language. This suggests, as described by Kapa and Plante (2015) that general domain deficits could cause the language difficulties observed in children with DLD.

Visual attention is one such function that is particularly relevant in DLD due to its intrinsic relationship with reading, where it is essential for word processing. It is currently known that there is a high comorbidity between language and reading disorders, with more than 50% of children with DLD having dyslexia and vice versa (Marshall et al., 2010). While attributing causality from one factor to the other is a matter of debate (McCardle et al., 2001; Catts and Kamhi, 2005), it has been suggested that phonological processing and visual attention may be affected in both conditions (Ehrhorn et al., 2021). Several theories of dyslexia and DLD suggest that, for example, phonological deficits of various types, when present in both disorders, play a key role in this overlap (Messaoud-Galusi and Marshall, 2010), recently demonstrating how language difficulties affect reading and the mediating role of phonological awareness (Catts and Kamhi, 2005).

Phonological awareness in children with DLD has been extensively studied across languages, but little is known about visuo-attentional performance in these children. Dispaldro and Corradi (2015) found that performance on visual attention tasks was significantly different from that of controls, suggesting that visuo-attentional processing may enable phonological processing. Other research has helped to clarify the role of visual attention in this population, as it is a skill that appears to be a critical component of working memory (Wais et al., 2012; Henry and Botting, 2017). For example, Finneran et al. (2009) found that children with DLD were slower than controls on visuospatial orientation tasks and less accurate on visual and auditory sustained attention tasks. Montgomery (2008) describes both anatomical-brain and behavioral differences in visual and auditory attention in children with DLD compared to their peers, with attentional processing being a critical component in DLD (Finneran et al., 2009).

The present study aims to characterize visual attention during phonological processing tasks in children with DLD, which, according to hypotheses on the causality of DLD, may have general domain limitations that cause the difficulties observed in the linguistic component (Kapa and Plante, 2015). As described by Dispaldro and Corradi (2015), these general domain difficulties lead to inadequate information processing with both linguistic and non-linguistic stimuli.

The approach of assessing by observing eye movements is emerging as an online research method that allows for the investigation of visuo-attentional and phonological processing (Bellocchi et al., 2013). Previous work, such as that of Desroches et al. (2006), suggests that the assessment of phonological processing using eye tracking is promising, based on the hypothesis that eye movements are linked to lexical processing, so that fixations on a target over time reflect the lexical activation of a word. These authors observed that eye movements in auditory word recognition are altered when the task involves knowledge of suprasegmental language skills (rhymes). These findings are at odds with conventional assessment and suggest that approaches and methods of assessment play a fundamental role in the study of phonological, visual, and auditory processing.

Considering that some research has proposed that visual processing seems to play an important initial role that precedes and enables phonological processing (Sargiani et al., 2015), and given that it is clear that DLD is associated with a deficit in phonological processing; the present study aims to identify the performance of visual attention in a task involving phonological processing in children with DLD in a transparent orthographic language such as Spanish, as measured by eye-tracking, in order to identify how children with DLD process this type of information.

2 Methodology

2.1 Participants

This cross-sectional correlational study involved 40 Colombian Spanish-speaking children aged 4–8. The study group consisted of 20 children with DLD, while the control group included 20 children without language difficulties. All participants attended school. To ensure similarity, the control group was selected to match the study group in terms of age and gender, resulting in a ratio of 15 boys to 5 girls in both groups. The sociodemographic data of the participants are shown in Table 1.

TABLE 1 Participant characterization.

	DLD group ($n = 20$)	Control group ($n = 20$)	Mann–Whitney *U*	*p*-value	*Z*
Age	6.5	6.5	200	1.00	0.000
Gender			200	1.00	0.00
Male	14	14			
Female	6	6			
SES			170	0.42	−0.92
Low	5	5			
Medium	9	12			
High	5	3			

Individuals included in the study group were diagnosed with language difficulties and their contacts were provided by schools and therapists. The inclusion criteria required that none of the children had other conditions such as autism, hearing loss, or intellectual disability that could explain the language impairments. Each participant underwent a language assessment battery to confirm the presence of difficulties in this specific area. In addition, a nonverbal intelligence assessment was administered to rule out any associated cognitive difficulties (Table 2).

2.2 Instruments and materials

Clinical Evaluation of Language Fundamentals CELF-Core Language Score.

The core language score is a measure of general language ability, informing clinical judgments regarding the existence or non-existence of language impairments, and determining the necessity for specialized educational interventions.

Two versions of the CELF have been administered: CELF Preschool 2 (Wiig et al., 2009) and CELF-4 (Semel et al., 2006), depending on the age of the children assessed. The former was used to assess children between the ages of 3 and 6.0 years (Sentence Comprehension, Word Structure Formulated Sentences, Recalling Sentences), while the latter was used for children older than 6.1 years (Word Classes, Formulated Sentences, Recalling Sentences, Semantic Relationships).

K-BIT 2—Kaufman Brief Intelligence Test, Second Edition (Kaufman and Kaufman, 1997).

In the present study, only the Nonverbal Scale was used, which focuses on the ability to make visual analogies and understand relationships, was used to determine whether there were severe cognitive impairments preventing the children from participating in the study.

Hispanic-American adaptation of the Peabody Picture Vocabulary Test (Dunn and Dunn, 1986), also known as *Test de Vocabulario en Imágenes Peabody* (TVIP).

The main purpose of this test is to assess an individual's level of receptive vocabulary and vocabulary acquisition. Its secondary purpose is the detection of difficulties in verbal skills to evaluate cognitive processes. This test has been widely used in scientific research.

Phonological Processing Assessment Test—PROFON (Lara-Diaz et al., 2011).

This test was used to assess the components of phonological processing at the level of phonological awareness, phonological memory and phonological naming. The measure of phonological awareness includes three levels: syllabic, intrasyllabic and phonemic. At the syllabic level, tasks included: initial syllable omission, final syllable omission, middle syllable omission, initial syllable substitution, final syllable substitution, and middle syllable substitution. At the intrasyllabic level, tasks included: onset deletion, rhyme deletion, rhyme substitution, rhyme substitution, rhyme pairing, phoneme deletion, and comparison judgment. At the phonemic level, tasks included: initial sound identification, final sound identification, segmentation synthesis, common words, non-words, segmentation analysis, backward words, and word play.

Eye Tracker Tobii TX 300.

The Eye Tracker is designed to measure eye movement and provide response times, visual fixations, and visual fixation counts of participants in real time as they perform a specific task.

The TX300 eye tracker consists of a 23″ detachable monitor. It has a sampling rate of 300 Hz and allows free head movement.

2.3 Procedures

A descriptive, cross-sectional, quasi-experimental study was conducted. The study had three main phases, which are described below:

Phase I: Search and selection of children: Participants were sought through direct contact with various professionals (speech therapists, occupational therapists, special educators, teachers, and psychologists), in addition to collaboration with educational institutions that allowed the selection of children who reported a language impairment. The final selection was made by means of inclusion–exclusion criteria. Participants who confirmed their availability to visit the facilities of the National University in order to apply the tests with the eye-tracking equipment were selected.

Phase II: Application of linguistic and cognitive tests: First, the informed consent form was signed by the parents and/or guardians and assented to by the minor. Two evaluation sessions of 45–60 min were held, during which the order of administration of the tests was randomized, a code was given to the participants to identify the envelope containing the tests, and the same code was used to identify the voice recordings made. Depending on the availability of the parents, the professionals conducted the tests at educational institutions, the children's homes or at the Center for Human Communication of the Faculty of Medicine of the National University of Colombia. All the tests previously described were applied and the indications of each of them were followed.

Phase III: The experimental phase consisted of assessing visual performance during the auditory recognition of images, with and without phonological distractors. Stimuli consisted of high-frequency bisyllabic words. The stimuli were tested with a group of children between the ages of 4 and 8 to determine the familiarity of the target words and their relationship to the image used. For the rhyme distractors, a pre-rhyme judgment was conducted with children of the same ages who did not participate in the study.

TABLE 2 Nonverbal cognition and language.

	DLD group (n = 20)	Control group (n = 20)	Mann–Whitney U	p-value	Z	1-β	d
KBIT	94.85 (7.809)	96.25 (8.77)	183.5	0.65	−0.448	0.98	0.31
CELF Core language	76.90 (7.52)*	103.85 (10.45)	0.50	0.000	−5.406	1.00	2.96

Standard deviation in parentheses, *$p < 0.05$.

During this phase, the children were introduced to the visual stimuli and asked to name each one. Adjustments were made and the name was checked to ensure it was correct, otherwise the participant was given feedback and the list was checked again at the end.

Twelve groups of four pictures were presented, with which the children performed an auditory–visual word identification task in which the phonological relation was manipulated with a target word, that is, with cohort or rhyming distractors.

The stimuli were presented on a 23″ screen at a distance of 50–60 cm with a resolution of 1,920 × 1,080 pixels (Figure 1).

The auditory stimuli consisted of bisyllabic words, in each presentation the children were given 3,000 ms to look at the pictures before hearing the instruction "look at the red dot" followed by the instruction "now look at (target word)." In order to provide no prior cue to the target word, neither the 3rd person direct complement atonic pronouns (*la,lo,el*) nor the corresponding indefinite articles (*un, una*) were used.

The Tobii TX300 eye tracker (version 3.2.1) was used to record eye movements at 300 Hz. Only data with a reliability percentage of more than 60% of the oculomotor recordings were taken into account.

Participants were seated in a fixed chair with an additional adjustable seat so that their eyes could reach a distance of 60 cm in front of the computer screen at a 90° angle to the screen. The background screen color was set to white. The calibration system was automated and a total of 9 points were scored. The calibration stimulus was a red dot on a white background.

In each screen, four images were presented, one of which was the target item and the others were three distractor images. The following types of distractors were used in the stimulus manipulation: (1) Pictures that were phonologically unrelated (baseline), (2) A distractor that rhymed with the target word (rhyme), (3) A distractor that began the same as the target word, with the same syllabic structure (cohort), (4) Two distractors, one cohort and one rhyming. Each target is delineated as an area of interest, and the Tobii Studio software identifies how the gaze is fixated on each of these areas. All data provided by the eye tracker were recorded. The time elapsed in milliseconds from the appearance of the stimulus to the first fixation in the area of interest, the number of visual fixations in the area of interest, and the time spent looking at the area are calculated, indicating the attention devoted to each stimulus. Through the

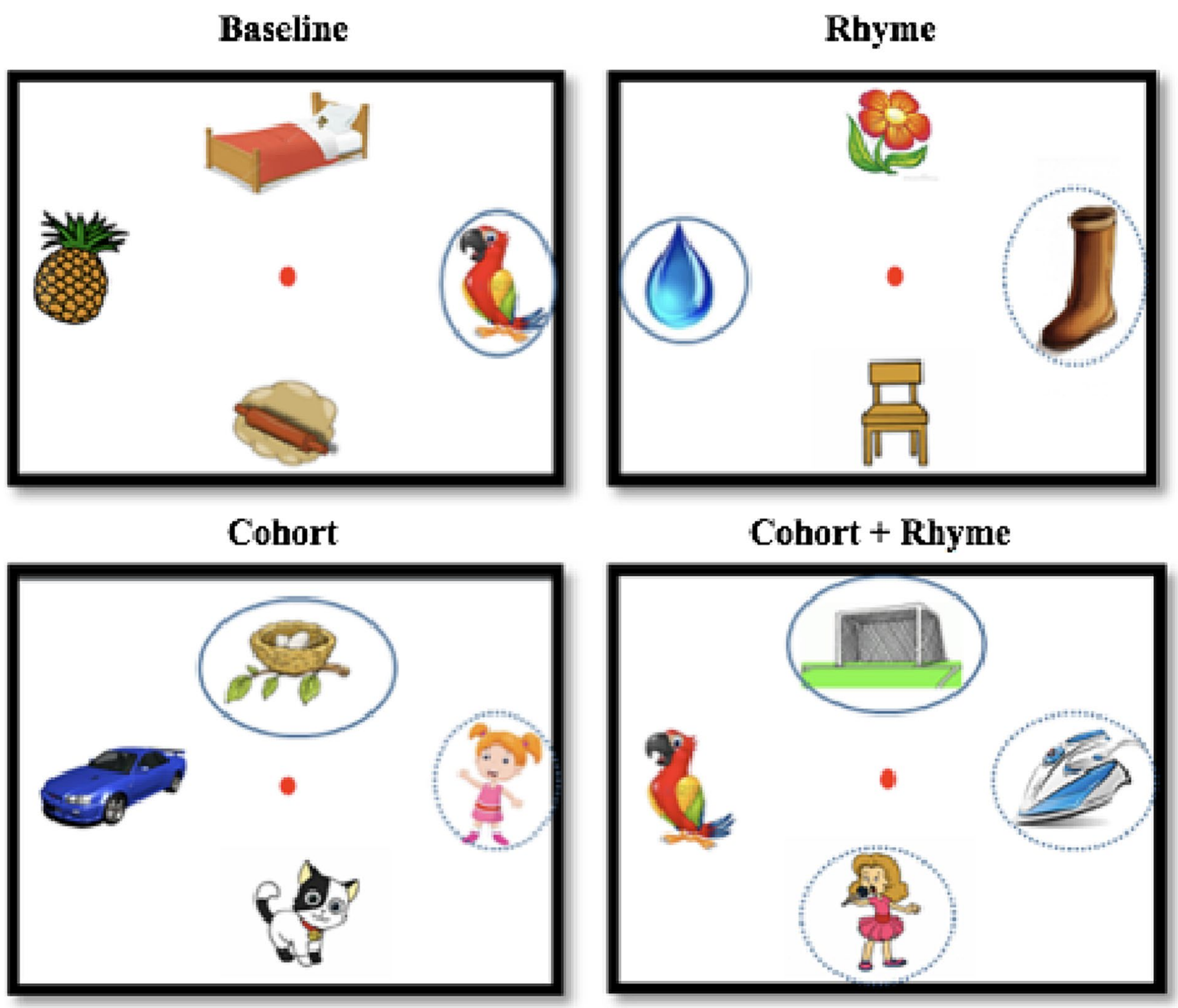

FIGURE 1
Example stimuli.

software, heat maps were also generated, visually indicating the concentration of fixations.

2.4 Data analysis

The data were recorded in the respective formats of the tests administered, and then the appropriate changes were made to the scalar scores and/or percentages as needed. Both the above-mentioned data and the data recorded by the eye tracker were transcribed into a database in the Microsoft Excel program.

Subsequently, an analysis was carried out using the computer package SPSS, version 17, where the appropriate descriptive statistics were calculated. Non-parametric analyses were performed, given the nature and size of the sample and the impossibility of assuming normality of the data.

The nonparametric Mann–Whitney U Test for independent samples was used to compare the means between the two groups for the different tests administered, with a significance level of 0.05. The effect size was calculated by Cohen's d using G*Power 3.1 statistical software (Faul et al., 2007). The d values are typically quantified as small (0.2), medium (0.5), and large (0.8) (Cohen, 1988).

The mean of the average fixations in the areas of interest (AOIs) of the correct item in each stimulus on eye tracking were calculated (Baseline, Cohort, Rhyme and Cohort + Rhyme). Measurements with a reliability of less than 60% were excluded because the evaluation was carried out on children; only data with a reliability of at least 70% were taken into account.

3 Results

The Mann–Whitney U analysis revealed significant differences between the groups in most of the domains evaluated, except for age and cognitive variables. The DLD group obtained lower scores in the areas of language, vocabulary, and phonological awareness (Table 3).

The non-parametric Friedman test was employed to examine whether there is an effect of condition for each of the groups (control and DLD).

For the control group, an effect of condition was found, specifically at baseline and cohort condition ($p = 0.013$), as well as for the pair of rhyme condition with cohort + rhyme condition ($p = 0.006$).

For the group with the disorder, there was no difference between baseline and rhyme condition ($p = 0.346$), but there was a difference for the baseline measurement condition and cohort ($p = 0.016$), and cohort + rhyme and rhyme condition ($p = 0.01$).

These results suggest that control children are sensitive to cohort and rhyme interference effects, which results in longer fixation latencies in the presence of these distractors. In contrast to the control group, the findings above indicate that children in the DLD group do not show differences in fixation times between baseline and rhyme, but they do show differences between baseline and cohort. This would indicate an interference effect when the words begin the same, but not when the words rhyme for children with DLD.

As mentioned above, the children were recorded by the eye tracker, which provides a record of eye movements through various modalities including heat maps (report that graphically establishes, in color scales, the portions in which greater visual fixations are made) and the areas of interest (AOIs) of the participants when looking at each item. Below are some of the heat maps and areas of interest that show the difference between the groups:

Figure 2 shows the heat map recorded by the control (A) and DLD (B) groups when faced with the visual recognition task with both cohort and rhyme distractors. It reveals a clustering of fixations on both distractors for the control group and on the cohort distractor for the DLD group. It is important to note that a higher density of fixations represents a greater cognitive effort in recognizing the target word.

In the same way, the following figure shows the performance for the same demand when only one phonological distractor is presented, i.e., Rhyme. In support of the above statistical data, Figure 3 shows how the phonological distractor presents higher concentrations of fixation duration (heat map) (B and D) and higher fixation amplitude in the area of interest in both the distractor and the target word (areas of interest maps) (A and C) in the control children compared to the children in the DLD group.

4 Discussion

This study compared the performance of visual attention in word recognition tasks when presented with phonological and lexical distractors to characterize the performance of children with developmental language disorders and controls. Previous studies indicate that phonological processing allows to encode information from the outside, to represent and manipulate it, to transform these representations, to create networks between them and to store them and to access them later (Betourne and Friel-Patti, 2003). Therefore, phonological processing is one of the components responsible for the preservation of language-based information.

Phonological processing skills are typically assessed through metalinguistic tasks such as phonetic discrimination, minimal pairs,

TABLE 3 Vocabulary and phonological awareness.

	DLD group ($n = 20$)	Control group ($n = 20$)	Mann–Whitney *U*	*p*-value	*Z*	1-β	*d*
TVIP	44.45 (15.95)*	64.55 (13.49)	58.5	0.000	−3.830	0.98	1.36
Syllabic PA	6.40 (3.13)*	11.75 (3.09)	51.5	0.000	−4.039	0.99	1.72
Inter-syllabic PA	4.20 (2.08)*	11.70 (3.96)	17.5	0.000	−4.972	0.99	2.37
Phonemic PA	3.25 (1.52)*	7.20 (2.06)	32	0.000	−4.583	0.99	2.18
Phonological awareness (PA)	13.80 (4.09)*	30.65 (8.47)	20.0	0.000	−4.876	1.00	2.53

TVIP: Peabody Test. Standard deviation in parentheses, *$p < 0.05$.

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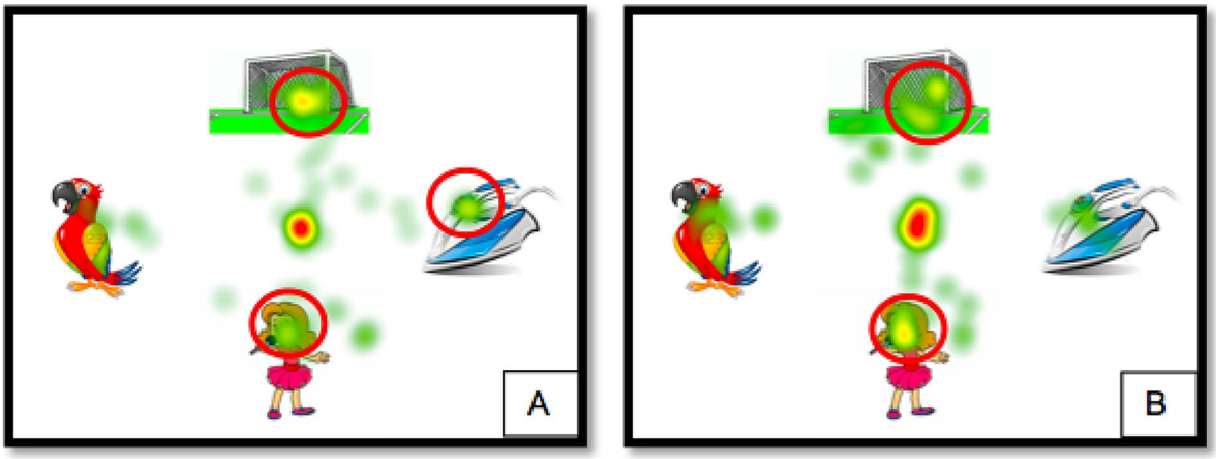

FIGURE 2
Cohort + Rhyme distractors. Item with target word *Cancha*, with two distractors: Cohort (*Canta*) + Rhyme (*Plancha*). Control Group **(A)** DLD Group **(B)**.

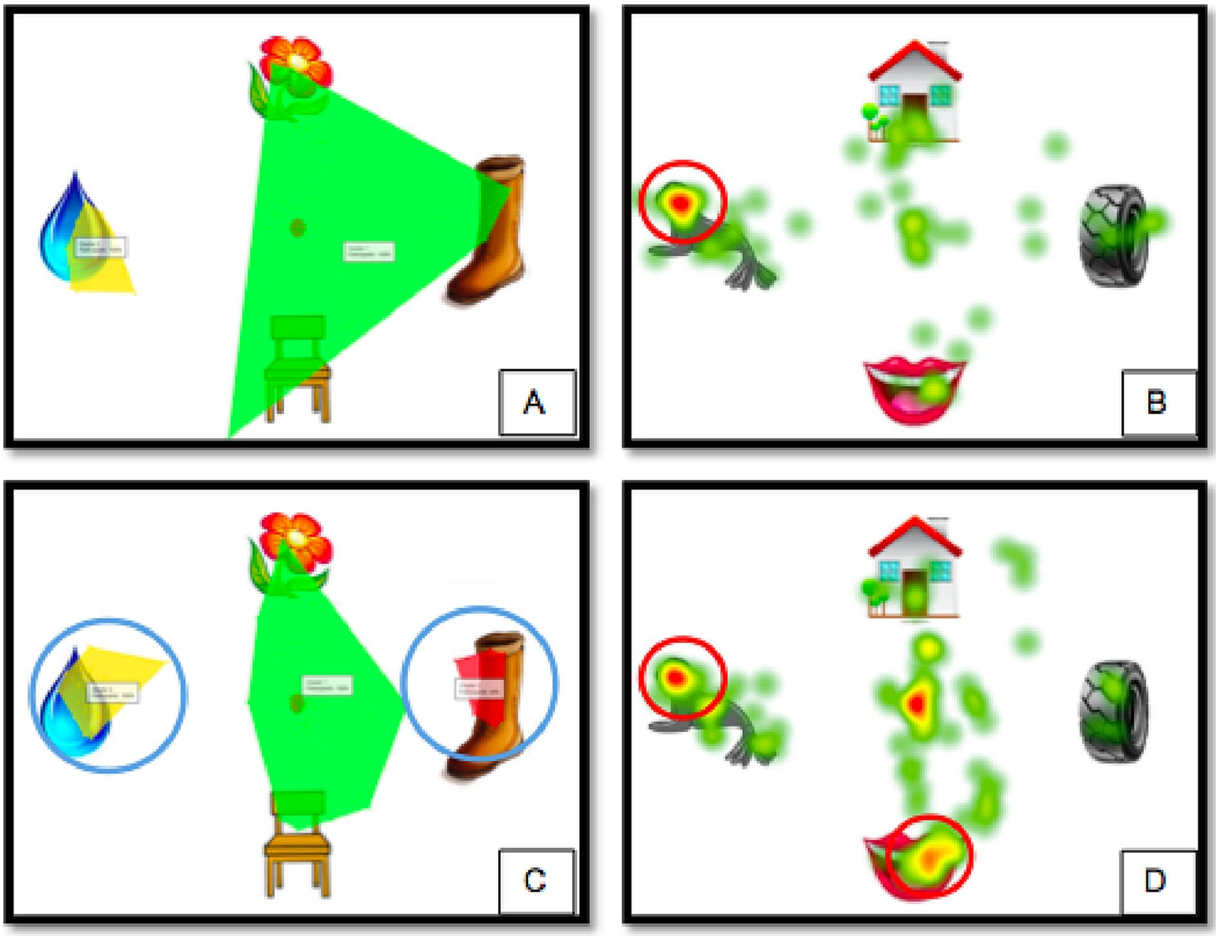

FIGURE 3
Rhyme distractor. Items with rhyme distractor. DLD Group **(A,B)** y Control Group **(C,D)**; Heat Maps with target word *Foca* and rhyme distractor *Boca*: **(B,D)**, Areas of interest with target word *Gota* and rhyme distractor *Bota* **(A,C)**.

phonological memory, omission, substitution and addition, syllabic and phonemic. These tasks are vulnerable to attentional and working memory processes and have an off-line approach that omits much important information at the perceptual, representational, productive and metaphonological levels. Thus, a visual assessment, as in the experiment presented above, could provide different information depending on the modality of presentation. Thus, a direct relationship between the cognitive deficit and the conduct disorder is postulated by the phonological theory.

According to the hypothesis that DLD has general and not specific domain limitations, it can be said that this phenomenon is due to the fact that they have an insufficiency in processing different cognitive resources, which would determine how much work can be done in a period of time. As a consequence, the difficulty in processing resources leads to inadequate information processing with both linguistic and non-linguistic stimuli (Dispaldro and Corradi, 2015). Consequently, processing limitations have been identified in terms of speed and capacity, with working memory and processing speed being the most studied.

Bellocchi et al. (2013) mention that the assessment approach by observing eye movements is valuable in relation to cognitive processing, as it increases the knowledge of visual-attentional processing in reading. Through real-time monitoring of spoken language processing, eyetracking has effectively shown that both groups and rhymes contend during recognition. Furthermore, these effects have been observed even without visually presented competitors by adjusting the neighborhood size of targets (Magnuson et al., 2003, 2007). In this sense, the research by Desroches et al. (2006) proposes a new approach to phonological assessment using eye tracking, based on the hypothesis that eye motions are linked to lexical processing, such that fixating on a target over time reflects the lexical activation of a word.

The results of the eye tracker task indicate that under normal circumstances, auditory word recognition in children with DLD does not show significant differences compared to the control group. Both groups showed similar eye movement speeds when presented with stimuli without any type of distractor (baseline), suggesting that the ability to identify isolated words is equivalent in both groups. In addition, both groups (DLD and Control) showed a slowness of fixation on the target stimulus when presented with a lexical distractor, i.e., Cohort, indicating that both groups were sensitive to this factor. Although the DLD group has lower scores on the TVIP test, it is likely that they may experience difficulties in the semantic component of language, But in this case, their performance is similar to that of the controls.

However, the control group displayed a slower response when presented with a phonological distractor, i.e., rhyme, in contrast to the DLD group, which showed the same level of performance as in the baseline test. This suggests that children with DLD can perceive the segmented information of words and rely on the retrieval of lexical information, as proposed by the model of speech perception (McClelland and Elman, 1986); but they are much less sensitive to identifying the phonological relationship, as is the case with rhyme, which may be related to the DLD group shows lower performance in phonological processing.

Although the control group also exhibited slower recognition in the presence of a rhyme distractor, the DLD group did not. This observation implies that DLD children possess the ability to perceive detailed segmental information about words, enabling them to quickly identify spoken words. However, they demonstrate significantly less sensitivity to higher-order rhyming relationships among words. This finding indicating that typically developing children naturally categorize auditory stimuli based on both segmental and suprasegmental properties, whereas children with DLD tend to prioritize segmental information. These results are similar to previous studies (Allopenna et al., 1998) and support other studies indicating that typically developing children naturally categorize auditory stimuli based on both segmental and suprasegmental properties, confirming that children with language disorders are less sensitive to phonological aspects of language (Aguilar-Mediavilla et al., 2002; Vandewalle et al., 2012; Buiza et al., 2016).

Consistent with the hypothesis presented in this study, the deficiencies in phonological processing did not interfere with visual attention for the recognition of the target word. However, it was thought that there would be a similar behavior with the cohort distractors, since it refers to a task of initial sound identification; yet, the TRACE model suggests that the cohort is a lexical facilitator (McClelland and Elman, 1986).

On the other hand, evidence shows that children with DLD fail to identify initial sounds in words on traditional tests; however, on the eye-tracker task, when presented with the cohort distractors, they show the same performance as children in the control group. It is possible that their problems in identifying initial sounds in words are due to difficulties in the explicit application of phonological knowledge, rather than an online processing deficit. If this is the case, it is possible that the metaphonological problems are adjacent to the phonological processing deficits that actually play a causal role in language difficulties, especially in DLD.

The findings regarding phonological processing with visual attention tasks suggest the relevance of using the eye tracker in diagnosis and assessment during treatment, as it is able to detect subtle processing deficits that cannot be detected by offline methods, such as traditional phonological awareness tests.

4.1 Clinical implications

This research contributes significantly to both the clinical and educational fields. It highlights that children with Developmental Language Disorder (DLD) often exhibit deficits primarily in the phonological component, which consequently affects the semantic component and visual attention. These deficits are also reflected in their performance on standardized language tests. As a result, this study underscores the importance of a differential diagnosis. Such a diagnosis not only identifies the disorder, which has a higher incidence than previously assumed, but also allows for subcategorization and the development of methodological strategies for detection, treatment, and mitigation in affected children. This approach will facilitate the creation of diverse models for diagnosis, treatment, school evaluation, and curriculum support.

Studying online processing in children enables us to delve deeper into cognitive processing. This is particularly crucial as many nuances occurring within milliseconds during complex language processing tend to be overlooked in typical tasks.

4.2 Limitations

Despite the prevalence of Developmental Language Disorder (DLD) in the Colombian population, the recruitment process for this research proved to be quite complex. Twenty children from both the

DLD and Control groups were excluded from the study due to difficulties encountered by parents and guardians in transporting them to the laboratory.

It is crucial to emphasize that the results presented here pertain solely to the sample involved in this study. Due to the limited number of participants, no generalizations can be made.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Faculty of Medicine, Universidad Nacional de Colombia. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

ML-D: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. JB: Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. YA: Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aguilar-Mediavilla, E. M., Sanz-Torrent, M., and Serra-Raventós, M. (2002). A comparative study of the phonology of pre-school children with specific language impairment (SLI), language delay (LD) and normal acquisition. *Clin. Linguist. Phon.* 16, 573–596. doi: 10.1080/02699200210148394

Allopenna, P. D., Magnuson, J. S., and Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: evidence for continuous mapping models. *J. Mem. Lang.* 38, 419–439. doi: 10.1006/jmla.1997.2558

Bellocchi, S., Muneaux, M., Bastien-Toniazzo, M., and Ducrot, S. (2013). I can read it in your eyes: what eye movements tell us about visuo-attentional processes in developmental dyslexia. *Res. Dev. Disabil.* 34, 452–460. doi: 10.1016/j.ridd.2012.09.002

Betourne, L. S., and Friel-Patti, S. (2003). Phonological processing and oral language abilities in fourth-grade poor readers. *J. Commun. Disord.* 36, 507–527. doi: 10.1016/S0021-9924(03)00035-2

Buiza, J. J., Rodríguez-Parra, M. J., González-Sánchez, M., and Adrián, J. A. (2016). Specific language impairment: evaluation and detection of differential psycholinguistic markers in phonology and morphosyntax in Spanish-speaking children. *Res. Dev. Disabil.* 58, 65–82. doi: 10.1016/j.ridd.2016.08.008

Catts, H. W., and Kamhi, A. G. (2005). *The connections between language and Reading disabilities*. London: Taylor & Francis.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. *2nd* Edn: Mahwah, NJ: Lawrence Erlbaum.

Desroches, A. S., Joanisse, M. F., and Robertson, E. K. (2006). Specific phonological impairments in dyslexia revealed by eyetracking. *Cognition* 100, B32–B42. doi: 10.1016/j.cognition.2005.09.001

Dispaldro, M., and Corradi, N. (2015). The effect of spatio-temporal distance between visual stimuli on information processing in children with specific language impairment. *Res. Dev. Disabil.* 45-46, 284–299. doi: 10.1016/j.ridd.2015.07.008

Dispaldro, M., Leonard, L. B., Corradi, N., Ruffino, M., Bronte, T., and Facoetti, A. (2013). Visual attentional engagement deficits in children with specific language impairment and their role in real-time language processing. *Cortex* 49, 2126–2139. doi: 10.1016/j.cortex.2012.09.012

Dunn, L. M., and Dunn, L. M. (1986). *TVIP: Test de vocabulario en imagenes Peabody: adaptacion Hispanoamericana = Peabody picture vocabulary test: Hispanic-American adaptation*. Circle Pines, MN: American Guidance Service.

Ehrhorn, A. M., Adlof, S. M., Fogerty, D., and Laing, S. (2021). Probing phonological processing differences in nonword repetition for children with separate or co-occurring dyslexia and developmental language disorder. *Sci. Stud. Read.* 25, 486–503. doi: 10.1080/10888438.2020.1849223

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G* power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Finneran, D. A., Francis, A. L., and Leonard, L. B. (2009). Sustained attention in children with specific language impairment (SLI). *J. Speech Lang. Hear. Res.* 52, 915–929. doi: 10.1044/1092-4388(2009/07-0053)

Guarnera, M., Commodari, E., and Peluso, C. (2013). Rotation and generation of mental imagery in children with specific language impairment. *Acta Paediatr.* 102, 539–543. doi: 10.1111/apa.12162

Henry, L. A., and Botting, N. (2017). Working memory and developmental language impairments. *Child Lang. Teach. Ther.* 33, 19–32. doi: 10.1177/0265659016655378

Kapa, L. L., and Plante, E. (2015). Executive function in SLI: recent advances and future directions. *Curr. Dev. Disord. Rep.* 2, 245–252. doi: 10.1007/s40474-015-0050-x

Kaufman, A., and Kaufman, N. (1997). *Test Breve de inteligencia de Kaufman: Manual*. Madrid: TEA.

Lara-Diaz, M. F., Aguilar, E., and Serra, M. (2011) Prueba de Evaluación del Procesamiento Fonológico-PROFON. Universidad Nacional de Colombia.

Leonard, L. B. (2014). *Children with specific language impairment*. Cambridge, MA, USA: MIT Press.

Magnuson, J. S., Dixon, J. A., Tanenhaus, M. K., and Aslin, R. N. (2007). The dynamics of lexical competition during spoken word recognition. *Cogn. Sci.* 31, 133–156. doi: 10.1080/03640210709336987

Magnuson, J. S., Tanenhaus, M. K., Aslin, R. N., and Dahan, D. (2003). The time course of spoken word learning and recognition: studies with artificial lexicons. *J. Exp. Psychol. Gen.* 132, 202–227. doi: 10.1037/0096-3445.132.2.202

Marshall, C. R., Ramus, F., and van der Lely, H. (2010). Do children with dyslexia and/or specific language impairment compensate for place assimilation? Insight into phonological grammar and representations. *Cogn. Neuropsychol.* 27, 563–586. doi: 10.1080/02643294.2011.588693

McCardle, P., Scarborough, H. S., and Catts, H. W. (2001). Predicting, explaining, and preventing Children's Reading difficulties. *Learn. Disabil. Res. Pract.* 16, 230–239. doi: 10.1111/0938-8982.00023

McClelland, J. L., and Elman, J. L. (1986). The TRACE model of speech perception. *Cogn. Psychol.* 18, 1–86. doi: 10.1016/0010-0285(86)90015-0

Messaoud-Galusi, S., and Marshall, C. R. (2010). Introduction to this special issue exploring the overlap between dyslexia and SLI: the role of phonology. *Sci. Stud. Read.* 14, 1–7. doi: 10.1080/10888430903242076

Montgomery, J. W. (2008). Role of auditory attention in the real-time processing of simple grammar by children with specific language impairment: a preliminary investigation. *Int. J. Lang. Commun. Disord.* 43, 499–527. doi: 10.1080/13682820701736638

Norbury, C. F., Gooch, D., Wray, C., Baird, G., Charman, T., Simonoff, E., et al. (2016). The impact of nonverbal ability on prevalence and clinical presentation of language disorder: evidence from a population study. *J. Child Psychol. Psychiatry* 57, 1247–1257. doi: 10.1111/jcpp.12573

Özcebeet, E., Noyan Erbas, A., and Karahan Tiğrak, T. (2020). Analysis of behavioural characteristics of children with developmental language disorders. *Int. J. Speech Lang. Pathol.* 22, 30–36. doi: 10.1080/17549507.2019.1571631

Pauls, L. J., and Archibald, L. M. (2016). Executive functions in children with specific language impairment: A meta-analysis. *J. Speech Lang. Hear. Res.* 59, 1074–1086. doi: 10.1044/2016_JSLHR-L-15-0174

Przybylski, L., Bedoin, N., Krifi-Papoz, S., Herbillon, V., Roch, D., Léculier, L., et al. (2013). Rhythmic auditory stimulation influences syntactic processing in children with developmental language disorders. *Neuropsychology* 27, 121–131. doi: 10.1037/a0031277

Sargiani, R. A., Maluf, M. R., and Bosse, M. L. (2015). O Papel da Amplitude Visuoatencional e da Consciência Fonêmica na Aprendizagem da Leitura. *Psicologia: Reflexão e Crítica* 28, 593–602. doi: 10.1590/1678-7153.201528318

Semel, E., Wiig, E. H., and Secord, W. A. (2006). *CELF 4. Clinical Evaluation of Language Fundamentals. Spanish Edition*. San Antonio, TX: The Psychological Corporation.

Sheng, L., and McGregor, K. K. (2010). Lexical–semantic organization in children with specific language impairment. *J. Speech Lang. Hear. Res.* 53, 146–159. doi: 10.1044/1092-4388(2009/08-0160)

Ullman, M. T., and Pierpont, E. I. (2005). Specific language impairment is not specific to language: the procedural deficit hypothesis. *Cortex* 41, 399–433. doi: 10.1016/s0010-9452(08)70276-4

Vandewalle, E., Boets, B., Ghesquière, P., and Zink, I. (2012). Development of phonological processing skills in children with specific language impairment with and without literacy delay: a 3-year longitudinal study. *J. Speech Lang. Hear. Res.* 55, 1053–1067. doi: 10.1044/1092-4388(2011/10-0308)

Wais, P. E., Martin, G. M., and Gazzaley, A. (2012). The impact of visual distraction on episodic retrieval in older adults. *Brain Res.* 1430, 78–85. doi: 10.1016/j.brainres.2011.10.048

Wiig, E. H., Secord, W. A., and Semel, E. (2009). Clinical evaluation of language fundamentals preschool, Spanish Edition. CELF-P2 Spanish. PsychCorp.