

An evaluation of syntactic-semantic processing in developmental dyslexia

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Abstract

Introduction. The main purpose of this study is to investigate whether children who have reading disabilities in an alphabetically transparent orthography show a syntactic processing deficit. This research focuses on exploring syntactic processing and the use of morphological markers by subjects with reading disabilities. We analyze these groups' execution of various tasks from the syntactic module of the SICOLE multimedia battery (Jiménez, et al., 2002), grouping them into three sets: gender and number agreement, grammatical structure and function words.

Method. A sample of 97 subjects was selected (52 boys and 45 girls). The design involves three groups according to reading level: one experimental group formed by 29 reading-disabled (RD) subjects in fourth grade; one control group of 41 good readers of equivalent age; and one control group of 27 subjects from second grade with equivalent reading level to the RD group.

Results. The RD children obtain lower scores in the global syntactic processing scale than normal readers of a younger age. When controlling for the effect of working memory, the deficit in syntactic processing is shown in gender and number agreement tasks, and not in grammatical structure or function word tasks.

Discussion. Findings suggest that the deficit in syntactic processing is determined by difficulties in phonological processing which characterize children with RD. Children with RD have more difficulty in processing gender and number agreement tasks since they are more phonologically demanding. On the other hand, these difficulties are not manifest as a deficit when the tasks provide contextual information, such as in the case of grammatical structure and function word tasks.

Keywords: Dyslexia, syntactic processing, reading level design, evaluation.

Introduction

The study of phonological skills in children with dyslexia has constituted the nucleus of the most relevant research in the last decade. However, the role of syntactic processing has received much less attention. Evidence of possible alterations in the syntactic level of dyslexic subjects arises from various electrophysiological studies and from students on comprehension of relative clauses.

Electrophysiological studies have shown that different processing stages may be affected in dyslexia. Differences in cognitive information processing are reflected in variations in spatial patterns and temporary courses of neural activity (for a review, see Brandeis, Vitacco & Steinhausen, 1994; Riccio & Hynd, 1996). The increases in range and in latencies are interpreted as evidence in favor of an alteration in syntactic processing, where a greater range indicates greater effort in information processing, and an increase in latency represents lower processing speed. Leiken and Breznitz (2002) find that significant differences exist between dyslexic subjects and normal readers in measurements of event-related evoked conditionals.

During the eighties, studies appeared showing the difficulty of dyslexic subjects to operate on sentences containing relative clauses, as compared to normal readers (Byrne, 1981). Initially it was assumed that there was a delay in the development of syntactic structures. However, Mann, Shankweiler and Smith (1984) performed a study where they showed that dyslexic subjects are most affected when repeating relative clauses. These results led the authors to conclude that there is not a syntactic delay, but that the problems are located in working memory. Problems in working memory led to the differences when processing sentences with relative clauses. In order to explore this hypothesis, that dyslexic subjects are able to process this type of sentence, as well as to manipulate syntactic information, Smith, Macaruso, Shankweiler and Crain (1989) manipulated the sentences with relative clauses in such a way as to decrease the load on working memory. Sentences with relative clauses contained two animated nouns, instead of three as in the 1984 study. Using the *token test* methodology (where the cards were replaced by toys), they presented four types of sentences with relative clauses: (a) the subject of the main clause is also the subject of the relative clause (SS) (e.g., The woman who was holding the umbrella kissed the man); (b) the subject of the main clause is the object of the relative clause (SO) (e.g., The man who was kissed by the woman was holding the umbrella); (c) the object of the main clause is also the subject of the

relative clause (OS) (e.g., The woman kissed the man who was holding the umbrella), (d) the object of the main clause is also the object of the relative clause (OO) (e.g., The woman kissed the man that the umbrella was covering). Results showed a significant effect from the type of sentences (sentences of type SO and OS were more difficult), and no significant effect was found by group. The authors take these results as proof that problems with relative clauses are not due to a delay at the syntactic level, but rather a deficit in syntactic processing. This study, however, is not free of criticism; mainly, that sentences such as, *The woman kissed the man that the umbrella was covering*, do not measure only syntactic processing. The subject's knowledge of the use of an umbrella (generally it covers persons and not other things), may help solve the task without limiting oneself to exclusively syntactic information. Additionally, only the toy that corresponded to the subject of the relative phrase would come up twice, meaning that after a few attempts the subject could carry out a non-linguistic strategy, inferring that one of the two toys represents the subject that is performing the action. For this reason, Bar-Shalom, Crain and Shankweiler (1993) performed a study in order to see whether experimental changes determined the changes in execution. They administered a similar task (although only one card or *token* was used instead of two) to 15 bad readers and 15 normal readers. Results showed that the bad readers performed significantly worse than the control group, and an interaction was found between the group and the sentence type. These results, together with earlier studies, lead the authors to conclude that in processing relative clauses the problem is not at the syntactic level but is due to a deficit in lower-level processes. These results were replicated by Nittrouer (1999).

On the other hand, results obtained with an elicitation task indicated that bad readers are able to produce relative clauses; however, they produce fewer clauses where the object is moving (e.g., The monkey that the cat scratched climbed up the tree). Bar-Shalom et al. (1993) take these results as evidence that bad readers have knowledge of syntactic structures, but limitations in their processing capacity affect their ability to understand such structures, especially when the load on working memory is increased. Bar-Shalom et al. (1993) explain that the underlying deficit in dyslexic subjects is found in phonological information processing. Furthermore, dyslexic children show difficulties in verbal working memory that can be attributed to difficulties in access or use of phonological structures. Additionally, children with dyslexia show serious difficulty in segmenting words into their sounds; due to this difficulty in processing phonological information, syntactic analysis is altered. That is,

the authors claim that the syntactic system itself is intact, only that its functioning is affected by the phonological deficit observed in these subjects.

Shankweiler et al. (1995) performed a study where they presented additional syntactic structures, such as passive sentences, in a judgment task involving pictures, to (1) subjects with reading and arithmetic disabilities, (2) children with arithmetic disabilities, (3) children with attention deficit, and (4) a control group. Subjects were to determine whether the sentence corresponded to a given picture. Results indicated that children with reading disabilities performed the tasks significantly worse than the control group, but execution was not differentiated among the remaining groups, suggesting that difficulties at the syntactic level are not specific to dyslexia. Nonetheless, the execution of the RD group was not equal to that of normal subjects.

Having got this far, the main purpose of this study is to investigate whether children with reading disabilities in a language with a consistent spelling system show a deficit in syntactic processing. In order to explore syntactic processing and the use of morphological markers in subjects with reading disabilities, we used a design of reading level in three groups (RD, NL, EC). We analyzed these groups' execution of various tasks from the syntactic module of the SICOLE multimedia battery, grouping them into three sets: gender and number agreement, grammatical structure and function words.

Method

Subjects

The study sample was composed of students from second and fourth grades in primary school. The subjects attended six different publicly-funded schools, located in urban areas in the towns of San Cristóbal de La Laguna and Santa Cruz de Tenerife. A prior selection was carried out initially based on teachers' criteria. Teachers were asked to select 4th grade students who performed well in reading tasks, 4th grade students who had reading problems (e.g. they read slowly, with excessive difficulty, etc.), and students from 2nd grade whose reading performance was normal. In order to establish a definitive experimental sample out of the 123 subjects initially selected, they were given IQ tests (Cattel's g-factor test), the syntactic-semantic module from the SICOLE multimedia batter, a verbal working memory task, word and pseudoword subtests from the PROLEC standardized reading test (Cuetos, Rodríguez & Ruano, 1996), and a naming task with words and pseudowords (Jiménez &

Rodrigo, 1994). We eliminated from the sample subjects who showed some sensorial or neurological problem or who had not had regular school attendance. Based on scores obtained by the subjects on the pseudoword subtest from the PROLEC test, and a naming task with words and pseudowords, we selected a final sample of 97 subjects (52 boys and 45 girls), with ages ranging from 7 to 10 years old ($M=9.15$; $SD=13.2$), and belonging to 2nd and 4th grades in primary school. Children were classified into three groups according to their reading level: (1) one experimental group with 29 RD subjects (19 boys and 10 girls) from 4th grade (age, $M=9.8$; $SD=5.6$); (2) a control group of 41 BL subjects (20 boys and 21 girls) of equivalent age to the prior group (age, $M=9.7$; $SD=5.4$); and (3) a control group of 27 BL subjects (13 boys and 14 girls) from second grade, with equivalent reading level to the RD group (age, $M=7.63$, $SD=4.2$). When selecting the RD subjects, we used a cutoff score of $PC < 25$ on the PROLEC pseudoword reading test (Cuetos et al., 1996) and with a reading level on the PROLEC words subtest equivalent to students in second grade. We also administered a word and pseudoword naming task. Children from the RD group did significantly worse in naming words $F(1.91)=13.02$, $p < .001$, and pseudowords $F(1.93)=45.69$, $p < .001$, than children from the EC group; and than children in the NL group in words $F(1.91)=8.38$, $p < .05$, and in pseudowords $F(1.93)=25.51$, $p < .001$. Likewise, we found significant differences between the RD group and the EC group in latency times for words $F(1.93)=29.02$, $p < .001$, and pseudowords $F(1.93)=37.74$, $p < .001$, and also with the NL group for words $F(1.93)=12.34$, $p < .001$, and for pseudowords $F(1.93)=17.75$, $p < .001$.

There were no significant differences in distribution of the subjects as a function of gender $\chi^2(2)=3.54$, $p=.17$, nor were there significant differences in CI, $F(2.94)=1.79$, $p=.17$. However, analysis of working memory showed significant differences between the groups $F(2.94)=5.44$, $p < .01$. A posteriori analysis of simple effects revealed that RD children scored significantly lower than the EC group $F(1.95)=10.9$, $p < .001$, but there were no differences with the NL group $F(1.94)=1.71$, $p=.19$. When analyzing the syllabic awareness tasks, no group effect was found ($F(2.79)=2.20$, $p=.118$, nor effect of group interaction by task, $F(1.154)=156.0$, $p=.376$). However, on the alphabetic knowledge task, RD children were significantly worse than children from the EC group, $F(1.78)=4.76$, $p < .05$, and than children from the NL group, $F(1.78)=7.43$, $p < .05$.

Design

This study made use of a reading-level design with three groups.

Instruments

Cattell and Cattell's "g" Factor (1950/1989). In order to evaluate non-verbal intelligence, we applied scale 1 (form A) for the group of younger readers and scale 2 for schoolchildren from 8-14 years of age.

PROLEC Evaluation Battery of reading processes in primary schoolchildren (Cuetos Rodríguez & Ruano, 1996). This test includes different reading subtests from which we administered: reading of letters, words and pseudowords.

Naming task. This task is integrated in the SICOLE (Jiménez, et al., 2002). It consists of reading aloud, as quickly as possible, verbal stimuli that are presented one by one on the computer screen. The computer records the answer and registers the reaction time (RT) to each stimulus from the time it appears on the screen until the subject emits the first sound of reading it. Words and pseudowords were presented to the subjects randomly in two independent sets. Reliability analysis was performed for the set of words and pseudowords. In both groups reliability was .97. The set of words was made up of 32 stimuli and the set of pseudowords, 48. In order to guarantee familiarity with the words, we consulted the normative study by Guzmán and Jiménez (2001). The pseudowords were drawn from the study by De Vega, et al. (1990). The sequence of administration of stimuli was: blank screen (200 ms.); presentation of the word or pseudoword framed by a rectangle in the center of the screen (400 ms.). In total, the time between stimuli was 2,000 ms. Before performing each of the tasks, subjects were presented with several examples in order to assure ourselves that they had understood the instructions.

Verbal Working Memory Test. This test consists of an adaptation of a task by Siegel and Ryan (1989), developed using a procedure proposed by Daneman and Carpenter (1980). Children listen to a sentence where the last word is missing, and they must orally add the word and complete the sentence. Next, the examiner reads another sentence which the child must also complete. Immediately following, the child is to repeat aloud the two words spoken. These must be remembered in the same order, the first word should correspond to the word used to complete the first sentence, and the second word should be the one used to complete the second sentence. If the answer is correct, a third sentence is given, otherwise the child is given another chance to complete this first level. There are three levels: 2, 3, 4, and 5 words. Administration of the test is over when the subject fails all attempts at one level.

Syntactic-semantic processing evaluation module from the SICOLE multimedia battery. This module comprises 6 tasks which evaluate proper use of gender and number agreement rules, proper use of function words and their involvement in assigning syntactic roles, and finally, we evaluate the subjects' execution of tasks involving knowledge of the syntactic structure of a sentence. Tasks which comprise this model were divided into three large groups:

(1) Gender and number agreement:

Use of gender: Subjects are presented with truncated sentences, they must read the words in the sentence and words which are proposed as alternatives for properly completing the sentence. Each blank space in the initial sentence is accompanied by two words differing in gender, only one of which will correctly complete the sentence.

Use of number. The task is identical to the previous one, except that the words presented as alternatives for completing the sentence differ in number.

(2) Grammatical structure:

Word order. Two sentences and one picture are presented. The subject must indicate which sentence corresponds to the picture. Sentences have subject-verb-object structure. The two alternative answers vary in that the subject and object roles are reversed.

Correct use of assigning syntactic roles. This task is similar to the word order task, a picture is presented, and a series of sentences (in this case three), where only one of them corresponds to the image presented. Two of the sentences are active, and differ in that one has the subject-verb-object syntactic structure, while in the second the structure is object-verb-subject, the third sentence presented as an alternative answer is a sentence in passive voice.

(3) Function words.

Function words. In order to evaluate function words, two types of exercises are used: the first consists of presenting two pictures at once, together with a sentence. Only one picture corresponds to the sentence presented. In order to solve the task, the child must be able to comprehend the meaning and the role that the function word plays in the initial sentence. The second type of exercise consists of presenting a sentence where one word is missing. Below the sentence there are two function words and one noun, only one of the function words will properly complete the sentence.

Procedure

Tests were applied individually and always during regular school hours. Students were transported to different schools where there was a room available free of noises and possible interruptions.

Results

An analysis of variance (ANOVA) was carried out with a factor of three levels (group: RD, NL, EC) using the global scale of scores in the syntactic module (total number of correct answers in all syntactic tasks) as dependent variable. The ANOVA showed significant differences between the groups in the global scale $F(2,79)=29$, $p < .001$. A posteriori analysis of simple effects confirmed that children in the RD group obtained worse scores on the global scale than normal, younger readers, $F(1,78)=57,92$, $p < .001$, and than normal readers of an equivalent chronological age $F(1,78)=45.16$, $p < .001$.

Next, data were analyzed using a 3 x 3 factorial design, with an intergroup factor with three levels (groups: RD, NL and EC) and an intragroup factor: type of task with three levels (gender and number agreement, grammatical structure and function words). Table 1 contains averages and standard deviations of the three groups for each of the syntactic tasks.

Table 1.
Means and standard deviations of IQ, age, naming task, reading of words and pseudowords, and working memory as function of each group

	Groups					
	RD		NL		EC	
	Mean	SD	Mean	SD	Mean	SD
IQ	112.2	16.0	111.0	9.8	117.6	18.3
Age	117.6	5.6	91.6	4.2	117.6	5.6
Naming words	.93	.05	.95	.04	.98	.02
Naming pseudowords	.74	.15	.89	.07	.92	.06
Reading words	28.6	1.26	29.6	.62	29.8	.52
Reading pseudowords	25.1	2.7	29.2	.65	29.7	.46
Working memory	2.6	0.7	2.9	0.7	3.2	0.8

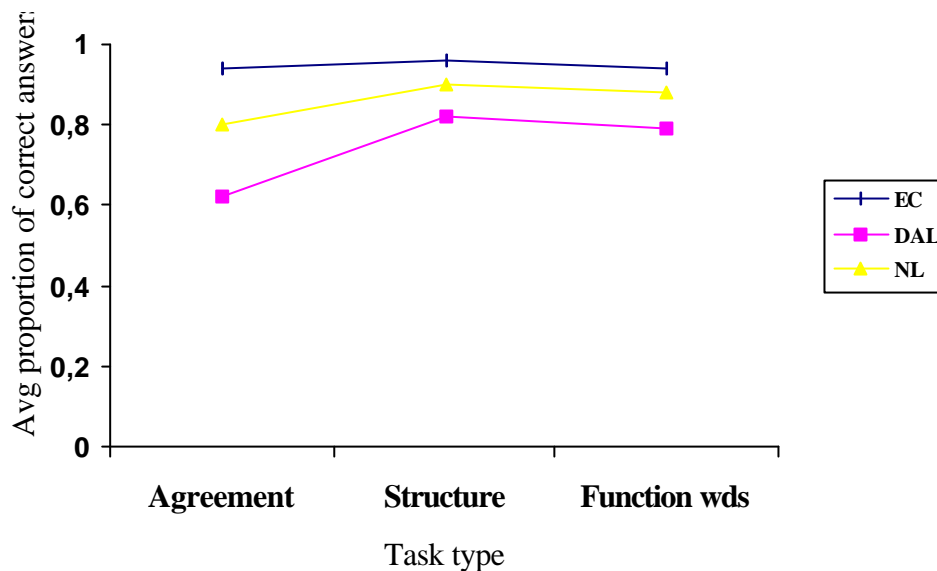
Two multivariate analyses of variance were performed: (1) analysis by participants (F1) and (2) analysis by items (F2). The intention was to be able to generalize effects obtained not only to other participants, but also to other items. As Perea and Rosa (1999) suggest: “if the effect is significant in the analysis by participants, but is not so in the analysis by items, the effect could be due to one or more words in one of the conditions having provoked the effect in the analysis by participants, thus limiting the scope of the results” (p. 82).

This analysis showed a main effect of Group $F(2,79)=25.03$, $p<.001$, $\eta^2=.39$, $F_2(2,29)=37.5$, $p<.001$, and a main effect of Task $F(2,78)=15.85$, $p<.001$, $\eta^2=.29$, $F_2(2,30)=3.63$, $p<.05$, but these main effects were mediated by a significant interaction of Group x Task $F(4,154)=4.83$, $p<.001$, $\eta^2=.13$, $F_2(4,60)=3.77$, $p<.01$. We performed a posteriori analyses of the simple effects, and results confirmed that children with reading disabilities performed significantly worse than subjects in the NL group in: gender and number agreement $F(1,79)=12.48$, $p<.001$; grammatical structure $F(1,79)=6.39$, $p<.05$; and function words $F(1,79)=5.25$, $p<.05$. When comparing groups EC and RD we found significant differences in all tasks, gender and number agreement $F(1,78)=38.20$, $p<.001$; grammatical structure $F(1,78)=22.20$, $p<.001$; and function words $F(1,78)=14.77$, $p<.001$. Additionally, the EC group was significantly better than the RD group on all tasks (gender and number agreement, $F(1,79)=50.03$, $p<.001$; grammatical structure, $F(1,79)=26.60$, $p<.001$; and function words $F(1,79)=19.72$, $p<.05$). Finally, differences between the groups EC and NL were also significant in gender and number agreement, $F(1,79)=7.44$, $p<.01$ and in grammatical structure $F(1,79)=4.16$, $p<.05$; however, in the function word tasks such differences were not found $F(1,79)=2.69$, $p=.205$.

Table 2
Means and standard deviations for each task of the syntactic-semantic module as a function of each group

	Groups					
	RD		NL		EC	
	Mean	SD	Mean	SD	Mean	SD
Gender and number agreement	.62	.25	.80	.15	.94	.08
Grammatical structure	.82	.15	.90	.09	.96	.07
Function words	.79	.21	.88	.11	.94	.06

Figure 1. Group x Task interaction in proportions of correct answers
RD: group of reading disabled students;
EC: group of good readers matched for age;
NL: group of young readers match for reading level.



As seen in the sample description, significant differences in working memory existed between the groups. Since differences found could be due to difference in working memory, we decided to control this variable in our analyses. For this reason, we performed analyses of covariance (ANCOVAs) where the covariant was working memory. Before performing the ANCOVAs, we checked the viability of doing so. We checked the influence of WM and the goodness of its use for this type of analysis. Results revealed a significant effect of WM on the global scale $F(1.76)=12.31, p <.001$; on agreement, $F(1.76)=12.66, p <.001$; on structure, $F(1.76)=9.14, p <.01$; and on function words $F(1.76)=9.10, p <.001$, indicating that the use of the ANCOVA is adequate.

An analysis of covariance (ANCOVA) was performed with a factor of three levels (group: RD, NL, EC) using the global scale of scores on the syntactic module as dependent variable. Bonferroni's correction was used for all the ANCOVAs in the study in order to reduce the probability of committing Type 1 errors. The ANCOVA showed significant differences in the groups on the global scale $F(2.78)=22.60, p <.001$. A posteriori analysis of the simple effects confirmed that children in the RD group performed significantly lower than normal, younger readers $F(1.78)=12.10, p <.001$.

Next, data were analyzed using a 3 x 3 factorial design, with an intergroup factor with three levels (groups: RD, NL and EC) and an intragroup factor: type of task with three levels (gender and number agreement, grammatical structure, function words). This analysis showed a main effect of Group $F(2,78) = 19.53, p < .001, \eta^2 = .33$, $F(2,29) = 37.5, p < .001$; and a main effect of Task $F(2,78) = 15.85, p < .001, \eta^2 = .31$, $F(2,30) = 3.63, p < .05$, but these main effects were mediated by a significant interaction of Group x Task $F(2,78) = 4.62, p < .001, \eta^2 = .11$, $F(4,60) = 3.77, p < .01$. We carried out a posteriori analyses of simple effects, and results confirmed that children with reading disabilities performed significantly worse on the gender and number agreement task as compared to subjects matched for reading level $F(1,78) = 10.29, p < .002$. When comparing groups EC and RD we found significant differences on all tasks: gender and number agreement $F(1,78) = 38.20, p < .001$; grammatical structure $F(1,78) = 22.20, p < .001$; and function words $F(1,78) = 14.77, p < .001$.

Discussion

The main purpose of this study was to investigate whether children with reading disabilities in an alphabetically transparent orthography show a deficit in syntactic processing. The present study demonstrates that children with RD obtain worse scores on the global scale of syntactic processing than do younger, normal readers, even when controlling for working memory. In light of these results, we can conclude that subjects with RD present a deficit in syntactic processing. Many studies in English have shown deficiencies in subjects with RD in syntactic processing (Byrne, 1981; Mann et al., 1984; Nitrouer, 1999; Shankweiler et al., 1995; Smith et al., 1989). Syntactic processing is fundamental for fluency and for effective text reading. Syntactic problems also influence the reading of simple words, such as the difficulty in recognizing the function of words, prepositions, auxiliary verbs, etc., in short, all those words which are difficult to recognize outside of a semantic context.

Once the syntactic processing deficit is determined, we seek to determine where this deficit is located. We examine the differences between different syntactic processing tasks, controlling or not controlling for working memory. Working memory refers to information retention in immediate memory, while new information is being processed and stored information is being recognized in immediate memory. Working memory is fundamental for reading because the reader must decode and/or recognize words while remembering those he or she has already read. Working memory is very important for reading words, particularly during the early stages of acquiring reading skills, since the rules for grapheme-phoneme

conversion for each segment of the word must be held in memory while new segments are processed. When working memory was not controlled, results indicated a deficit in all tasks, since subjects with RD performed significantly worse when compared to younger subjects matched for reading level. However, when controlling for WM, a deficit only in the gender and number agreement task appeared.

These results lead us to suggest that the deficit in syntactic processing is determined by difficulties in phonological processing which characterize children with RD (Jiménez, 2002). Dyslexic children have problems when segmenting words into sounds (Jiménez, 1997). Likewise, dyslexic persons show particularly poor performance in the pronunciation of pseudowords (Jiménez & Hernández-Valle, 2000). An experiment carried out by Perfetti, Goldman and Hogaboam (1979) showed that dyslexic persons tend to compensate for this difficulty by relying much more on the context than do normal readers. In that study, they measured the time that children took in order to pronounce printed words. In one case, isolated words were presented; in a second case, words were presented as part of a story. Although both groups benefitted from context, inexpert readers benefitted more. Apparently, inexpert readers try to compensate for their difficulty by giving greater weight to contextual information. This fact may explain the absence of a deficit in grammatical structure and function words tasks, since these tasks were presented with pictures that could give contextual information to the child, which could then be used to solve the task. However, the gender and number agreement task, where no visual support existed, implies a greater phonological load. As a consequence, difficulty in phonological information processing in children with RD can inhibit them from correctly performing the syntactic analysis. Along these lines, Bar-Shalom et al. (1993) suggested that the underlying deficit in dyslexic subjects is located in the processing of phonological information. Additionally, they indicated that dyslexic children showed difficulties in verbal working memory that could be attributed to difficulties in access or in utilization of phonological structures. They concluded that children with RD do possess syntactic structures, but their limited processing capacity affected the analysis of such structures. Our results showed that subjects with RD presented a deficit in syntactic tasks when we did not control for WM in our analysis. However, when this source of variability was controlled, there were no differences between children with RD and the younger readers in the handling of grammatical structure and in function words, although performance was still worse than normal subjects matched for age. Analysis of syntactic factors indicates to us that children with RD present certain delays in handling structural morphology and that they

make little use of segmentary traits, overlooking important linguistic signals that help the rest of us in text comprehension.

With regard to diagnosis and treatment, from the preceding discussion we deduce the important role of disabilities in verbal processing, since Reading Disabilities are disabilities related to the translation of visual input into verbal or auditory-based codes.

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