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Syntactic Awareness and Arithmetic Word Problem Solving in Children With and Without Learning Disabilities

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Abstract

Arithmetic word problem (AWP) solving is a highly demanding task for children with learning disabilities (LD) since verbal and mathematical information have to be integrated. This study examines specifically how syntactic awareness (SA), the ability to manage the grammatical structures of language, affects AWP solving. Three groups of children in elementary education were formed: children with arithmetic learning disabilities (ALD), children with reading learning disabilities (RLD), and children with comorbid arithmetic and reading learning disabilities (ARLD). Mediation analysis confirmed that SA was a mediator variable for both groups of children with reading disabilities when solving AWPs, but not for children in the ALD group. All groups performed below the control group in the problem solving task. When SA was controlled for, semantic structure and position of the unknown set were variables that affected both groups with ALD. Specifically, children with ALD only were more affected by the place of the unknown set.

Keywords

dyscalculia, dyslexia, problem solving, mathematics, syntactic awareness

There are several deficits underlying arithmetical performance in children with learning disabilities (LD), making the identification and the study of cognitive phenotypes that define the disorder a challenge for researchers and professionals. A learning disorder can result from deficits in the ability or the process of representing information in one or more of the domains that compose the mathematical cognition, or in one or a group of individual competencies within each domain (Geary, 2004). Mathematical ability, in fact, seems to depend on the integration of two distinct systems: a core nonsymbolic representation of the quantities and a late verbal processing (Dehaene & Cohen, 1995, 1998; Lemer, Dehaene, Spelke, & Cohen, 2003). As development proceeds, symbolic and nonsymbolic requirements of the mathematical tasks make the integration of these representational systems crucial. Most of the tasks that measure arithmetic performance combine verbal and quantitative processing, as in the case of arithmetic word problem (AWP) solving, which requires the integration of linguistic information and mathematic processing skills (Ostad, 1998; Vicente, Orrantia, & Verschaffel, 2008). When a child is faced with the AWP solving task, she or he must build a model or representation of the problem that allows deducing the proper calculation to obtain the correct result (Jitendra, DiPipi, & Perron-Jones, 2002; Kintsch & Greeno, 1985). As proposed by Kintsch and Greeno (1985), the propositional structure of the AWP triggers the mental model to represent the problem and to infer the correct operation for solution. Thus, to understand and represent AWPs correctly, one needs to pay attention not only to this specific numerical information in the text but also to the situation and the events described in the problem (Hegarty, Mayer, & Monk, 1995; Orrantia, Tarín, Múñez, & Vicente, 2011), where semantic and syntactic information must play an important role. Integration of verbal and numerical information when representing AWPs depends on many factors: quantity processing measured as arithmetical knowledge and procedural arithmetic (Vukobic & Lessaux, 2013a, 2013b) or counting, quantity discrimination, and number naming (Jordan, Glutting, & Ramineni, 2010); central executive and phonological components of working memory, concept formation, and fluid intelligence (Fuchs et al., 2010; Swanson, Jerman, & Zheng, 2008); and linguistics skills such as reading comprehension (Bisschop, Jiménez, Rodríguez, Villarroel, & Peake, 2013), verbal general ability, and phonological skills (Vukobic & Lessaux, 2013a, 2013b).

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Syntactic awareness (SA) can be defined as children's ability to manage the grammatical structures of language. Although its influence on AWP solving has not been investigated directly, it is a variable that could mediate the problem representation process (Kintsch & Greeno, 1985). The fact that the integration of verbal and numerical information that composes the AWPs plays a role, specifically in children with LD, makes this an interesting variable to study. During elementary education, normally achieving children show a rapid development of grammatical skills, but, as demonstrated by Siegel and Ryan (1988), children with reading LD have a significantly delayed sensitivity to the grammatical structures of language. According to these authors, these deficits were specific to children with dyslexia and were absent in children with attention-deficit/hyperactivity disorder (ADHD) or disabilities in calculation, but they did not test this ability in groups of both LD in comorbidity.

Several studies have shown that the groups formed by children with arithmetic learning disabilities or dyscalculia (ALD) should be considered different from groups of children with ALD and reading learning disabilities or dyslexia (RLD) in comorbidity, as the nature and expression of their deficits appears to be different (Fletcher, 2005; Fuchs & Fuchs, 2002; Geary, Hamson, & Hoard, 2000; Jordan & Hanich, 2000). Children with ALD should have an advantage over their peers with both disorders in comorbidity (ARLD) in skills involving verbal processing, or those mediated by language (e.g., exact calculation of arithmetic facts or AWPs), whereas this advantage would disappear on tasks that depend on numerical magnitudes or visuospatial processing (Hanich, Jordan, Kaplan, & Dick, 2001). In the study of Fuchs and Fuchs (2002), ALD and ARLD groups did not differ in solving arithmetic computations, but the comorbid group showed lower performance on the more complex AWPs.

Geary and Hoard (2001) suggested that the co-occurrence of learning difficulties in math and reading may reflect a more general deficit in the representation or retrieval of semantic memory. In this way, Jordan, Kaplan, and Hanich (2002) noted the relation between mathematics and language pointing that reading skills influence child's mathematical development, whereas mathematical ability is not involved in reading development.

It is commonly assumed that comorbidity indicates the presence of the attributions of both conditions. However, the results of different studies are consistent with the idea that groups of children with ALD only and ARLD present different kind of difficulties and, as such, do not have comorbid associations, whereas groups of RLD and ARLD do present the same type of disorders, displaying a comorbid association (Fletcher, 2005). On the other hand, Andersson (2008, 2010) demonstrated results that disagree with these statements, showing that children with ALD and ARLD had weaknesses in several areas of mathematical cognition, without being able to demonstrate that children who had dyscalculia only had an advantage over children with both disorders when they solved AWPs. This deficit might be connected with difficulties in the representation of the AWP or the development of a solution plan.

Carpenter and Moser (1983) proposed a classification for AWPs based on their semantic structure, postulating four types of problems: change, compare, combine, and equalize. Another way to classify the AWPs is based on the position of the unknown set in the problem, and thus we can find the unknown in the first, second, or third position. In a study conducted by García, Jiménez, and Hess (2006), they showed that semantic structure was a variable that affected differently the children depending on the group, although this variable by itself is not enough to determine the difficulty of the items. The variable that was most relevant for this purpose was the position of the unknown set: The problems with the unknown set in the first term were the most difficult (Carpenter & Moser, 1983; García et al., 2006; Powell, Fuchs, Fuchs, Cirino, & Fletcher, 2009). Powell et al. (2009) supported the results presented by García et al. (2006), finding that the semantic structure affected differently children with LD, especially children with ALD and ARLD, than children without LD. On the other hand, to our knowledge, no studies have assessed whether these variables may play a role in the difficulty of the AWPs for children with dyslexia and to what extent they affect performance in this population.

There are linguistics aspects that influence the performance on AWP solving. Moreover, these linguistic aspects may play different roles in different learning disabled groups, which gave rise to the aim of our study. We were interested in examining the role of SA in AWP solving and the way that this metalinguistic skill exerts an influence over semantic structure and position of the unknown set in children with LD. Our prediction was that SA mediates AWP solving, especially for both reading disabled groups (RLD and ARLD). We were interested in how SA affects performance in different semantic structures of the problems and in different positions of the unknown set in children with LD. In this regard, an interaction effect between group and each within factor (semantic structure and place of the unknown set), when controlling for SA, will contribute to explaining the differences between groups. From a exploratory point of view, we were also interested in how semantic structure and position of the unknown set affect children with dyslexia only.

Method

Participants

A total sample of 449 children of primary education was assessed on their arithmetical performance (procedural calculation and solving AWPs) and specific linguistic variables

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Table 1. Classification Criteria for Different Groups With and Without LD.

	Percentile			
Group	PCA	TWR	TNWR	ANWR
ALD	<25	<75	<75	>25
RLD	>25	>75	>75	<25
ARLD	<25	>75	>75	<25
ND	>25	<75	<75	>25

Note. ALD = arithmetic learning disabilities; ANWR = accuracy in pseudoword reading; ARLD = arithmetic and reading learning disabilities; LD = learning disabilities; ND = non–learning disabilities; PCA = Arithmetic Calculation Task; RLD = reading learning disabilities; TNWR = time in pseudoword reading; TWR = time in word reading.

Table 2. Participants Characteristics (N = 449).

		Sex		Age	
Group	*n*	Male	Female	*M*	*SD*
ALD	33	18	15	9.03	1.26
RLD	138	67	71	8.9	1.23
ARLD	64	39	25	9.18	1.43
ND	214	103	111	9.00	1.17

Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; ND = control group; RLD = reading learning disabilities group.

(reading achievement, oral comprehension, and SA). These children were recruited from six schools, between second and fifth grade, in the Canary Islands, Spain. Four of these schools were located on the island of Tenerife, the two remaining on the island of Gran Canaria. Groups were formed based on their performance profile on arithmetic and reading tasks, as specified in Table 1. In all, 33 children belonged to the arithmetic disabled group, 138 children to the reading disabled group, 64 children to the comorbid group, and 214 children to the control group. Children who had specific educational needs due to mental retardation, giftedness, motor, visual, or hearing impairment (permanent or temporary), or pervasive developmental disorders, behavioral disorders, ADHD, or special personal conditions due to delayed incorporation within the educational system were not included in the sample.

No differences were found between groups regarding sex, $\chi^2(3) = 3.69$, $p = .296$, or age, $F(3,445) = 0.759$, $p = .517$. Table 2 contains participant characteristics according to age and sex.

Materials

The *Prueba de Cálculo Aritmético* (PCA; Arithmetic Calculation Task; Artiles & Jiménez, 2011a) is a paper-and-pencil test consisting of 37 items, including addition, subtraction, multiplication, division, and fraction problems. The test was administered collectively, in each class of each course of the six schools. The maximum application time is 30 minutes. This task yields a reliability value (Cronbach's alpha) of .88.

This study used three subtests of the PROLEC-R (Cuetos, Rodríguez, Ruano, & Arribas, 2006), which assesses reading performance in children in primary education in Spanish. These subtests were Word Reading, Pseudoword Reading, and Oral Comprehension.

Word Reading. The Word Reading subtest of PROLEC-R consists of the written presentation of 40 words, which students must read aloud while total execution time and the number of errors are measured. In this study we used execution time for the classification of children in the reading disabled groups. Internal consistency, based on accuracy, gives a Cronbach's alpha of .74.

Pseudoword Reading. In the Pseudoword Reading subtest of PROLEC-R, 40 pseudowords are presented to students while the examiner records the total execution time of the task and the number of errors. Both indices were taken as criterion variables for the classification of children in the reading disabled groups. Internal consistency, based on accuracy, gives a Cronbach's alpha of .68.

Oral Comprehension. The Oral Comprehension subtask of PROLEC-R is composed of two texts that the examiner reads aloud to the child. Immediately after reading each text, the student is asked four questions, also presented orally, and the student has to reply according to the text. The texts consist of 78 and 118 words each, and they are both descriptive texts. Accuracy is recorded, and the internal consistency value (Cronbach's alpha) is .67.

In the *Spanish Oral Cloze Task* (Jiménez, Mazabel, O'Shanahan, & Siegel, 2009), a maximum of 20 sentences in which a word is missing are presented orally to the children. A neutral tone is reproduced in the place of the missing word, and the child should respond with a semantically and syntactically consistent word. The target words are functional words and words with meaning. If the child does not respond correctly to three example items or to the first three assessment items, the test is ended. This task measures syntactic knowledge of the child through her or his ability to generate syntactically matching words in sentences. This test yields a reliability value (Cronbach's alpha) of .87.

The *Problemas Verbales Aritméticos* (PVA; Arithmetic Word Problems Task; Artiles & Jiménez, 2011b) is composed of 33 items in the form of AWPs. These problems can be solved by using summation, subtraction, multiplication, or division. All of them are solved with a single arithmetic operation. They do not contain irrelevant information. Addition and subtraction problems can be classified by

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Table 3. Descriptive Data by LD Group and Correlations Matrix for Observed Variables.

	AWP Solving		SA		OC	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
ALD	5.57	6.18	14.94	4.05	3.64	2.21
RLD	8.71	7.23	13.09	4.3	3.57	1.93
ARLD	6.16	6.49	11.06	5.1	2.84	2.15
ND	12.36	6.77	14.89	3.37	4.01	1.99
AWP	—					
SA	.41**		—			
OC	.43**		.41**		—	

Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; AWP = arithmetic word problem (based on 20 additions and subtractions); ND = control group; OC = oral comprehension; RLD = reading learning disabilities group; SA = syntactic awareness.
***p* < .01.

their semantic structure, following Carpenter and Moser's (1983) model; thus, we can find change, compare, combine, and equalize problems. The problems differ in the position of the unknown set; that is, the unknown set is in the first, second, or last position. The PVA was administered individually; items were read aloud to the children. There was no time limit, but the task ended after four consecutive errors. The PVA yields a reliability value (Cronbach's alpha) of .95. For the purposes of this study, only responses to addition or subtraction problems were recorded. Therefore, the task was reduced to 20 items: 6 change AWPs, 6 compare AWPs, 6 equalize AWPs, and 2 combine AWPs, based on the classification of Carpenter and Moser (1983; Cronbach's alpha reliability value for the 20 items is .95, and when only change, compare, and equalize problems are used this value is .94). The PVA is designed to assess the counting strategy used by the student, although these data were not used for this study.

Procedure

The data collection for this study included AWP solving and arithmetic calculation. Also, tests were administered to assess reading achievement, oral comprehension, and SA for the same children. Specifically, children were assessed with the PCA (Artiles & Jiménez, 2011a). Reading performance was assessed with the PROLEC-R (Cuetos et al., 2006), specifically the Word Reading and Pseudoword Reading subtasks.

Results

This study analyzed the influence that SA exerts on AWP solving of children with different types of LD, compared to a control group. To test the hypothesis of mediation of the SA on AWP solving, we conducted a mediation analysis with each group as the predictive variable (ALD group as X_1, RLD group as X_2, and comorbid group as X_3), problem solving as the dependent variable (Y), SA as the mediator (M), and oral comprehension as the covariate. Correlations between the observed variables introduced in the analysis are shown in Table 3.

Following Hayes and Preacher (in press), levels of the group variable were transformed into three dummy variables to fit in the mediation model. Each of the dummy variables expressed on the model must be interpreted as a function of belonging to the specific LD group versus the control group. The mediation analysis was carried out by means of a multiple linear regression using the PROCESS macro for SPSS (Hayes, 2013). The indirect relative effect for each group was estimated using the nonparametric bootstrapping procedure (Hayes, 2013; Hayes & Preacher, in press). This procedure has been reported to be superior to the causal steps method of Baron and Kenny (1986) due to greater statistical power when testing the significance of the indirect effect. The indirect effect was bootstrapped with 5,000 replications. The mediation model explained 28% of the variance. The mediation effect was significant only for the RLD and comorbid groups as their relative indirect effect was significant (95% CI = −0.93, −0.14 for the RLD group, 95% CI = −1.9, −0.63 for the comorbid group). Table 4 shows estimated coefficients for each group path in the mediation model. The b path coefficient was statistically significant ($B = 0.45$, $SE = 0.07$), $t(448) = 6.31$, $p < .001$.

Relative effects (total, direct, and indirect) are reported in Table 5.

The mediation model is shown in Figure 1.

Once we found a mediation effect of SA on AWP solving, we were interested in the performance of the LD groups when controlling for this metalinguistic variable. We conducted a two-way ANCOVA, with Group (ALD vs. RLD vs. ARLD vs. ND) as the between-subjects variable and semantic structure (change vs. compare vs. equalize) as the within-subject variable, performance in AWP solving as the dependent variable (number of correct responses), and SA as the covariate. Note that for this analysis, combine problems

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Table 4. Estimated Coefficients for Each Group Path in the Mediation Model.

	a Path			c Path			c' Path		
Group	*B*	*SE*	*t*	*B*	*SE*	*t*	*B*	*SE*	*t*
ALD	0.45	0.57	0.77	–5.08**	1.18	–4.28	–5.29**	1.13	–4.66
RLD	–1.07**	0.39	–2.73	–1.83**	0.66	–2.77	–1.34*	0.64	–2.07
ARLD	–2.56**	0.63	–4.03	–3.34**	0.93	–3.59	–2.17*	0.95	–2.28

Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; RLD = reading learning disabilities group.
$^{*}p < .05$. $^{**}p < .01$.

Table 5. Relative Effects (Total, Direct, and Indirect) of the Mediation Model.

	Relative Effect				
Group	Effect	*SE*	*t*	LLCI	ULCI
ALD					
Total	–5.08**	1.18	–4.28	–7.41	–2.75
Direct	–5.29**	1.13	–4.66	–7.51	–3.06
Indirect	0.2	0.26		–0.31	0.74
RLD					
Total	–1.83**	0.66	–2.77	–3.13	–0.53
Direct	–1.34*	0.64	–2.07	–2.61	–0.06
Indirect	–0.49***	0.19		–0.93	–0.14
ALD + RLD					
Total	–3.34**	0.93	–3.59	–5.17	–1.51
Direct	–2.17*	0.95	–2.28	–4.04	–0.3
Indirect	–1.17***	0.31		–1.9	–0.63

Note. ALD = arithmetic learning disabilities; LLCI = lower limit of confidence interval; RLD = reading learning disabilities; ULCI = upper limit of confidence interval.
$^{*}p < .05$. $^{**}p < .01$. ***Statistical significance after 5,000 bootstrapping replications.

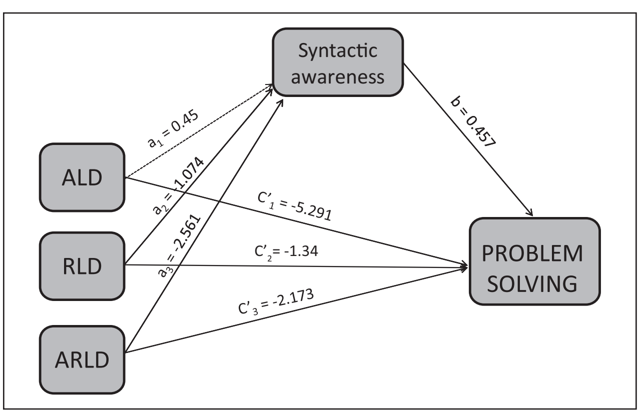

Figure 1. Model of mediation pathway of LD groups on arithmetic word problem solving with syntactic awareness as the mediator and oral comprehension as covariate.
Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; RLD = reading learning disabilities group.

were removed because the problem solving task included only two items of this type of AWPs and this was considered insufficient for the analysis of variance. Results show an interaction effect between group and semantic structure, $F(5.33, 790.24) = 2.67$, $p < .05$, $\eta^2 = .01$, a main effect of group, $F(3, 444) = 14.13$, $p < .001$, $\eta^2 = .08$, and a main effect of semantic structure, $F(1.78, 790.24) = 13.57$, $p < .001$, $\eta^2 = .03$ (degrees of freedom corrected by Huynh–Feldt for both the within-subject factor and the interaction). All LD groups performed lower than the control group, $t(246) = 5.57$, $p < .001$, for ALD group; $t(351) = 3.58$, $p < .01$, for RLD group; and $t(277) = 3.89$, $p < .01$, for the comorbid group. Change problems were easiest for all groups, $t(10) = 12.10$, $p < .001$, for change versus compare and $t(10) = 17.24$, $p < .001$, for change versus equalize; there were no differences between compare and equalize problems, $t(10) = 0.23$, $p < .06$. Simple effect tests resulted in larger differences between change and compare problems for the ALD group when compared to the control group, $F(1, 445) = 9.35$, $p < .01$, and for the comorbid group when compared to the control group, $F(1, 445) = 5.94$, $p < .05$. Figure 2 shows group means in solving AWPs by semantic structure.

Moreover, we conducted a two-way ANCOVA, with group (ALD vs. RLD vs. ARLD vs. ND) as the between-subjects variable and position of the unknown set (unknown

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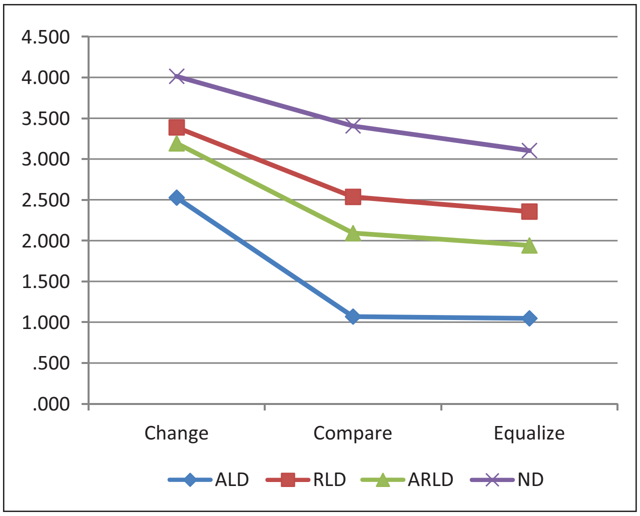

Figure 2. Mean groups in solving arithmetic word problems (AWPs) by semantic structure.
Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; ND = control group; RLD = reading learning disabilities group.

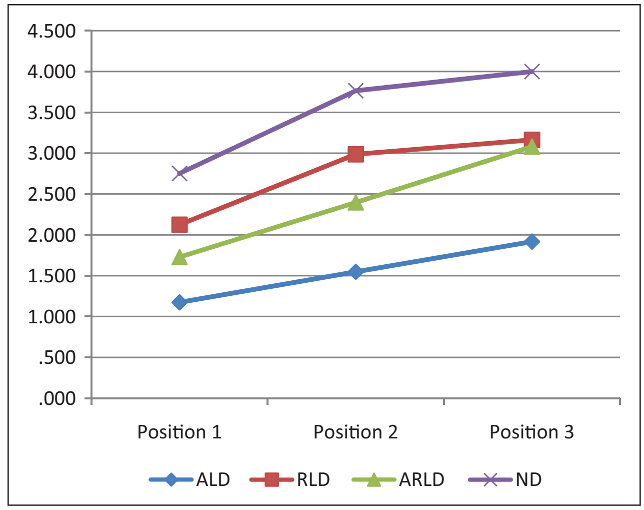

Figure 3. Mean groups in solving arithmetic word problems (AWPs) by position of the unknown set.
Note. ALD = arithmetic learning disabilities group; ARLD = comorbid group; ND = control group; RLD = reading learning disabilities group.

set in the first position vs. in the second position vs. in the third position) as the within-subject variable, performance in AWP solving as the dependent variable (number of correct responses), and SA as the covariate. Note that for this analysis we took into account only 18 problems and did not include combine problems. Results showed an interaction effect between group and position of the unknown set, $F(5.74, 852.04) = 2.74$, $p < .05$, $\eta^2 = .01$, a main effect of group, $F(3, 445) = 14.22$, $p < .001$, $\eta^2 = .08$, and a main effect of semantic structure, $F(1.91, 852.04) = 8.72$, $p < .001$, $\eta^2 = .01$ (degrees of freedom corrected by Huynh–Feldt for both the within-subject factor and the interaction). All LD groups performed lower than the control group, $t(246) = 5.57$, $p < .001$, for ALD group; $t(351) = 3.58$, $p < .01$, for RLD group; and $t(276) = 3.91$, $p < .01$, for the comorbid group. Simple effects tests resulted in larger differences between problems with the unknown set in the first position and in the second position for children with ALD compared to the control group, $F(1, 446) = 4.42$, $p < .05$, and for children in the comorbid group compared to control children, $F(1, 446) = 10.24$, $p < .001$. Simple effects also resulted in larger differences between problems in the first position and in the third position for children in the ALD group when compared to control group, $F(1, 446) = 4.08$, $p < .05$. Figure 3 shows group means in solving AWPs by position of the unknown set.

Discussion

The aim of this study was to determine the role that syntactic knowledge plays on AWP solving and the way this skill affects performance in groups of children with LD in arithmetic, reading, and both disorders in comorbidity. We were particularly interested in how SA affects performance. To this end, LD groups performed a task of SA, and we used this measure to assess its effect in solving the AWPs. We also analyzed whether the semantic structure and the position of the unknown set in the problem affected the solution of AWPs in these groups of children with LD and the effect that SA exerts over these variables.

The novelty of this study is that for the first time the mediation effect of SA on performance in AWP solving in children with LD has been examined. Furthermore, this is the first study, as far as we know, that investigates whether the semantic structure and the position of the unknown set may affect children with dyslexia in AWP solving.

Our results indicate that SA affects AWP solving, especially mediating the performance of the groups with dyslexia (with or without arithmetic disabilities) in the problem solving task. Total and direct relative effects of the mediation analysis show a lower performance in the problem solving task for children with ALD, when compared with the control group, than for children with RLD only or for those who present both LD in comorbidity, also compared with controls. Only relative indirect effects for children with dyslexia (with or without ALD), via SA, are statistically predictive of problem solving. In other words, all LD groups had lower performance than controls in the problem solving task, especially those having only arithmetic LD, who presented the strongest impairment in solving AWPs. Moreover, difficulties in this task for children in reading LD and comorbid LD groups are mediated by SA. In this regard, SA is explaining an amount of variance of the difficulties that these two groups with dyslexia present when solving

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AWPs. This is reasonable since AWP solving requires the integration of quantity and verbal demands (Ostad, 1998; Vicente et al., 2008). More specifically, AWP solving requires management of syntactic structures in the problem text to generate problem models which, in turn, are needed to plan the correct solution. When considering whether these groups of children differ in their SA, through the *Spanish Oral Cloze Task* (Jiménez et al., 2009), we found that groups with RLD (RLD and ARLD) have a deficit in their syntactic knowledge, compared to controls, and that it mediates the problem solving task, as we expected. These findings support those presented by Siegel and Ryan (1988), who found that children with dyslexia showed a deficit in SA, unlike their peers with dyscalculia, who did not show this deficit.

Moreover, we found that children with LD, regardless of their difficulties in arithmetic, reading, or both, performed lower on the AWP solving task than their peers without LD. Both groups of children with arithmetic LD differed in their performance on the problem solving task; especially children with ALD only showed a more pervasive pattern of performance than children in the comorbid group. This finding contradicts those of previous studies (Fletcher, 2005; Fuchs & Fuchs, 2002; Geary et al., 2000; Hanich et al., 2001; Jordan & Hanich, 2000), which suggested that both groups have different characteristics that are specifically reflected in those task involving verbal demands within the arithmetic domain, where the comorbid group should show a more pervasive pattern due to their verbal difficulties. This explains our results that when controlling for SA, difficulties for children in the comorbid group are substantially attenuated, as we can confirm in the drops in values when comparing the total relative effect and the indirect relative effect of this group.

On the other hand, we were interested in the performance of the dyslexic group on the problem solving task. Results showed a lower performance for these children, compared to controls, what supports the claim of Simmons and Singleton (2008), who argued that impairments of these children are not limited to reading and spelling. They suggested that the phonological processing deficits of children with dyslexia impair aspects of mathematics that rely on the manipulation of verbal codes. As we see in the mediation model, estimated coefficients for direct relative effects (path c') showed a significant negative prediction of problem solving, which indicates low performance on the task for all groups, compared to controls. Even after controlling for SA, impairments of children with dyslexia only must be due to other linguistic factors as well, presumably their phonological deficits, which could be impairing their ability to recall numerical facts to help them to solve the problem (Simmons & Singleton, 2008). Moreover, differences in performance for these groups of LD must be understood following Orrantia and Múñez (2013), who found evidence for the activation of an analog magnitude-based mental representation during AWP solving. This could explain that achievement of both groups with dyscalculia (ALD and ARLD) is lower, compared to the control group, as we can confirm the larger values for c' path estimated coefficients. In this sense, their deficit representing magnitude could lead them to fail in the task. This analog magnitude-based mental representation deficit during AWP solving seems to be especially relevant to the ALD only group.

Another objective of this study was to investigate the role that the semantic structure of the AWPs and the position of the unknown set play when children with LD are compared on a problem solving task while controlling for SA. In this sense, change problems were the easiest problems for all students, followed by compare and equalized problems, which represent the same difficulty. On the other hand, we found also that problems with the unknown set in the first position were the most complex, followed by those with the unknown set in the second position, and problems with the unknown set in the last position, which were easiest for all children. These results, especially regarding the place of the unknown set, are supported by previous studies (Carpenter & Moser, 1983; García et al., 2006), noting the importance of this variable to determine the difficulty of the items, and therefore performance in solving AWPs. Regarding the interaction, we found that change problems were much easier than compare problems for children in the arithmetic disabled group and for children in the comorbid group, compared to controls.

Furthermore, for both groups with arithmetic disabilities the problems with the unknown set in the first position were more difficult than those with the unknown set in the second position, when compared with controls. Moreover, the ALD group found more difficulties solving problems with the unknown set in the first position than those with the unknown in the third position, when compared to the control group. On the other hand, no differences were found when comparing the difficulty of different levels of semantic structure or position of the unknown set in children with dyslexia only versus controls. When SA is controlled for, children with dyslexia are not affected by these variables, unlike both groups with arithmetic disabilities, who are affected by them in different ways. Position of the unknown set, as previous research demonstrated (Carpenter & Moser, 1983; García et al., 2006), is the best variable to determine the difficulty of the problem and to discriminate between groups of LD. Children with arithmetic disabilities only, who do not rely on syntactic process to solve the problems, showed a pattern where the difficulty increased while finding the unknown set were less intuitive. Unlike them, children with comorbid disabilities, whose arithmetic problem solving is mediated by SA, showed a different pattern, in which the only difference in difficulty was between problems with the unknown set in the first versus the second position. In sum, semantic structure and

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position of the unknown set seem to be classifications based on mathematical processes, which accords with previous research (Orrantia & Múñez, 2013).

Different studies have pointed out that the process by which children with ALD represent the problem to trigger a correct solution plan seems inadequate (Andersson, 2008; Kintsch & Greeno, 1985; Mayer & Hegarty, 1996). According to the model proposed by Kintsch and Greeno (1985), this representation can be inferred from the propositional structure of the problem, in addition to keywords and numerical information from the text, what would make syntactic processing very relevant for the task. The results of our study agree with the idea that syntactic information plays a role in AWP solving, and in fact it influences the achievement of LD samples, as has been shown in the mediation analysis.

It has been observed that there are cognitive variables that exert an effect over SA. Verbal working memory system has shown to be specialized in interpreting aspects of sentence comprehension, specifically when assigning syntactic structure to determine the meaning of the sentence (Caplan & Waters, 1999). We were not able to record working memory variables, and that should be considered a limitation of this study. Future research could test the influence of working memory in this design. Furthermore, assessing problem solving and SA processes was based on single task methods, which is another limitation. Future replications of this design should be based on multiple measure methods.

There is still much research to be done to specify how children infer a representation model of AWPs, and it is possible that these populations of children with LD differ in their representing process. Future studies should investigate the representation process of the problem, taking into account the findings presented here. In addition, this line of research has important educational implications: Academic curricula should be sequenced taking into account the development of the cognitive systems that underlie the AWP solving processes, which in turn would support and facilitate learning processes. SA, as other linguistic and quantity processes, has been shown relevant to understanding and representing AWPs, being the semantic structure and the position of the unknown set key features to determine the difficulty of this task. Teachers at school must emphasize, in parallel, the development of syntactic processes that will support achievement in AWP solving.

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