STRATEGY CHOICE IN SOLVING ARITHMETIC WORD PROBLEMS: ARE THERE DIFFERENCES BETWEEN STUDENTS WITH LEARNING DISABILITIES, G-V POOR PERFORMANCE AND TYPICAL ACHIEVEMENT STUDENTS?

Juan E. Jiménez González and Ana Isabel García Espinel

Abstract. **This study was designed to test whether there are differences between children with arithmetic learning disabilities, garden-variety (G-V) poor performance and typically achieving children in strategy choice when solving arithmetic word problems. Using the standard-score discrepancy method (differences between IQ and achievement standard scores), samples were selected of dyscalculic, G-V poor mathematics performance, and typically achieving students. The groups were compared to analyze whether there were differences in their strategy choice when solving arithmetic word problems. No significant differences were found between dyscalculic and G-V children, both groups relying more on backup strategies than the nonimpaired group. Thus, the IQ-achievement discrepancy does not seem to be a relevant criterion for differentiating between individuals with dyscalculia and those with garden-variety poor mathematics performance.**

JUAN E. JIMÉNEZ GONZÁLEZ, Ph.D., is professor, University of La Laguna, Canary Islands, Spain.
ANA ISABEL GARCÍA ESPINEL, Ph.D., is assistant professor, University of La Laguna, Canary Islands, Spain.

Arithmetic, reading and writing make up the basic instrumental learning of the early school years. Understanding the basic ideas about arithmetic is the first step toward acquiring the higher levels of mathematical knowledge required in the labor or academic fields of our increasingly technological society. However, despite the importance of these first steps, results reflect high levels of failure, with mathematics seen as an unattractive subject ill adjusted to children's interests or possibilities (Ginsburg, 1997). This may partly be because mathematics is a complex subject with many cognitive demands (Rivière, 1990) that are not always taken into account in the teaching methodology used, or are not always within a subject's abilities when first taught mathematics.

In addition, traditionally, some of the individuals who fail at mathematics show a specific inability for mathematics. For example, many researchers have found that students with arithmetic learning disabilities (ALD) have more difficulty with mathematics than their peers without this difficulty (Ackerman, Anhalt, & Dykman, 1986; Goldman, 1989). Badian (1983) and

Kosc (1974) found that about 6.4% of children have specific difficulties with mathematics. One of the areas where children with ALD have deficits is in solving simple story problems (Miller & Mercer, 1997; Ostad, 1998; Parmer, Cawley, & Frazita, 1996; Russell & Ginsburg, 1984). Solving arithmetic word problems (SAWP) has been considered an important area of individual differences (Cummins, 1991; Cummins, Kintsch, Reusser, & Weimer, 1988; Hegarty, Mayer, & Green, 1992; Hegarty, Mayer, & Monk, 1995; Jaspers & van Lieshout, 1994; Swanson, Cooney, & Brock, 1993) as well as an area of deficiency in children with ALD (Mercer & Miller, 1992; Miller & Mercer, 1997; Russell & Ginsburg, 1984). However, fewer studies have been conducted on problem-solving abilities in young children with mathematics difficulties than on computational skills (Jordan & Hanich, 2000).

A number of studies (e.g., Carpenter & Moser, 1982; Carpenter, Hiebert, & Moser, 1981) have demonstrated that semantic structure is more relevant than syntax in studying children's solutions of addition and subtraction problems. Carpenter and Moser (1983) proposed a classification of word problems as a function of semantic structure: Change, Combine, Compare and Equalize.

In the Change problems there is an initial quantity and a direct or implied action that causes an increase or decrease in that quantity. For example, "Antonio had 18 stickers. His friend Paco gave him 6 more stickers. How many stickers does Antonio have altogether?" Combine problems involve the static relationship among a particular set and its two disjoint subsets. For example, "There are 12 sheep in a van, 4 are black and the rest are white. How many white sheep are there?" Compare problems also involve a static relationship, with a comparison of two distinct, disjoint sets — "Oscar's bicycle has 14 gears and Anita's bicycle has 9 gears. How many fewer gears does Anita's bicycle have than Oscar's?" Finally, the same sort of action is found in the Equalize problems as is in the Change problems, but based on the comparison of two disjoint sets. For example: "My dress has 12 buttons. If my sister's dress has 5 buttons more, it will have the same number of buttons as my dress. How many buttons does my sister's dress have?"

Research has shown that skill in solving these types of story problems gradually increases during elementary school, with Change and Combine problems being the easiest and Compare problems the most difficult (Riley & Greeno, 1988). Moreover, each of these types of word problems, though having the same semantic structure, varies in difficulty depending on which value in the problem is unknown. Therefore, to understand children's problem-solving skills, the identity of the unknown quantity must also be taken into account (Riley, Greeno, & Heller, 1983).

Cognitive analysis of the mathematics abilities of children with ALD also shows deficiencies in their use of strategies to retrieve number facts from memory (Geary, Brown, & Samaranayake, 1991; Jordan & Oettinger, 1997; Russell & Ginsburg, 1984). Various studies have shown that young children use a wide variety of strategies to resolve basic arithmetic operations. These strategies are organized in three basic categories: direct modeling, counting and number facts (Carpenter & Moser, 1982, 1983, 1984; De Corte & Verschaffel, 1987; Hiebert, Carpenter, & Moser, 1982; Siegler, 1986; Wynn, 1990).

Material strategies or direct modeling refers to situations where the child uses physical objects to represent the quantities that appear in the problem and to work out the answer. In verbal strategies, or counting, the child uses his or her fingers as a register or control of the verbal sequence, counting up or down, either silently or aloud. This can be detected by observation of the child's nodding, foot- or pencil-tapping, and so on. There are two categories of mental strategies: (a) *strategies based on direct memory (number facts)*. These present no difficulties for the child as there are combinations of numbers stored in long-term memory and automatic; and (b) *strategies based on the use or application of derivation rules, rules of numerical composition and decomposition*. These strategies are acquired in a developmental sequence, with the pattern of acquisition varying within age groups depending on arithmetic competence (Geary, 1990; Geary & Brown, 1991; Groen & Parkman, 1972; Siegler, 1986; Siegler & Robinson, 1982).

Russell and Ginsburg (1984) found that children with ALD differ from typically achieving children in the retrieval of number facts. More recent research (Geary, 1990; Geary & Brown, 1991; Geary et al., 1991; Geary, Widaman, Little, & Cormier, 1987; Goldman, Pellegrino, & Mertz, 1988) has suggested that children with ALD use strategies that tend to be developmentally immature; that is, they tend to use strategies that are often used by younger typically achieving children. The use of less mature problem-solving strategies is partly related to an immature or abnormal development of representations of the number facts in long-term memory (Garnett & Fleischner, 1983; Geary et al., 1987; Goldman et al., 1988). Jordan and Oettinger (1997) studied calculation and problem solving in two subgroups of children with ALD: one group with specific difficulties in mathematics and another with deficiencies in reading as well as mathematics. Their results confirmed that the difficulties of children with specific deficiencies were related to the retrieval of number facts from memory, whereas the group with more general difficulties had deficiencies that were more associated with the conceptualization and resolving of problems.

Another factor contributing to ALD is the existence of relatively poor working memory resources. In fact, this deficit contributes to the failure to develop adequate representations of number facts in memory (Geary & Brown, 1991). Empirical evidence suggests that the difficulties of individuals with ALD are related to problems in retrieving information from working memory (Hitch & McAuley, 1991; Siegel & Ryan, 1989; Swanson, 1994).

However, none of the previously mentioned studies of ALD analyzed the cognitive differences between individuals with ALD and "garden-variety poor mathematics performance" (G-V) children — those who show poor arithmetic achievement in accordance with their intellectual capacity. Therefore, the recent question of the cognitive nature of ALD has been left unanswered: whether IQ should be taken as the selection criterion for individuals with ALD; that is, whether discrepancy (the difference between IQ and achievement standard scores) is a decisive criterion in identifying these subjects (Siegel, 1989; Stanovich, 1989). The discrepancy criterion necessarily implies certain assumptions (Siegel 1989; Toth & Siegel, 1994): (a) intelligence tests are able to measure intellectual potential, (b) intelligence and performance are independent and the presence of learning difficulties does not affect IQ scores, and (c) dyslexic individuals defined as such according to the discrepancy criterion are qualitatively different from poor learners with low IQ scores (i.e., no discrepancy).

The validity of the last assumption, in particular, has been questioned. Many studies have shown no evidence that dyslexics and poor readers are different in reading or spelling skills or other basic cognitive processes (Jiménez & Rodrigo, 1994; Stanovich & Siegel, 1994). Siegel (1992) showed that the areas where subjects with dyslexia and poor readers differ were less related to the fundamental processes involved in reading than the areas where there were no differences. Further, Toth and Siegel (1994) found after reviewing 21 studies that explicitly compared poor readers and dyslexics, more similarities than differences between these groups in reading tasks such as word recognition, decoding, comprehension, and orthographic and phonological awareness. Most of the differences between the dyslexics and poor readers were limited to IQ-correlated tasks such as mathematics, vocabulary, and syntax.

The term ALD has been reserved for children with discrepancies between intelligence and mathematical ability. As in the case of reading disability, it has been assumed that there are important etiological, neurological, and cognitive differences between high-IQ and low-IQ poor mathematics performance children. However, Jiménez and García (1999) did not find significant differences between dyscalculic subjects classified according to the discrepancy criteria and subjects who were poor in arithmetic but did not show IQ-performance discrepancy. In solving arithmetic word problems (SAWP), both groups were equally affected by the semantic structure and the position of the unknown quantity in the problems.

In the present study, we wanted to test whether there were differences between ALD and G-V poor mathematical performance children in other cognitive processes involved in the solution of arithmetic word problems, such as the strategies used to resolve basic arithmetic operations (modeling, counting or number facts retrieval). We only considered the strategies used by the students during the solution execution phase (Mayer, 1986; Mayer, Larkin, & Kadane, 1984).

In summary, the main purpose of this research was to examine whether children with ALD and those with G-V poor mathematics performance differ in cognitive processes such as strategy choice when solving arithmetic word problems. If these groups are not different in strategy choice when solving arithmetic word problems, the criterion based on the IQ-achievement discrepancy is not relevant to the differentiation of the groups.

METHOD

Participants

A sample of 148 Spanish children was obtained. The children came from urban zones and from average socioeconomic backgrounds, from several state schools. Their ages ranged from 7 years 1 month to 9 years 4 months ($M = 7.81$; $SD = .67$). Using the standard-score discrepancy method, the children with mathematics difficulties were classified into two groups based on the difference, or lack of it, between their IQ scores and standard scores on the arithmetic subtest of the *Batería de Aptitudes Diferenciales y Generales* (BADYG; Yusté, 1985). Children with mathematics difficulties were defined as those who had percentile scores of < 25 on the BADYG Arithmetic subtest. Children were classified as having ALD (24 male, 36 female), if their arithmetic standard score was more than 15 points lower than their IQ score ($N = 60$) and if their score on an IQ test was > 80. Children were considered G-V poor mathematics performance (22 males, 22 females), if their arithmetic score was less than 15 points lower than their IQ score ($N = 44$) and if their score on an IQ test was > 80. The remainder of the children were defined as nondisabled (15 male, 29 female) because of scores > 30th percentile on the BADYG Arithmetic subtest ($N = 44$) and if their score on an IQ test was > 80.

There were no significant statistical differences in the distribution of the subjects as a function of gender $\chi^2 = 2.36$, $p < .30$. Neither was there a significant effect of age in solving arithmetic word problems, $t = 1.13$;

$p < .26$. Children with mathematics difficulties were receiving educational support in the resource classroom a few hours a week. Children who had sensory deficits, acquired neurological deficits, or other problems traditionally used as exclusionary criteria for LD were excluded.

Procedure

A first sample of children was selected according to teachers' opinions about (a) which children had specific difficulties with mathematics but did not have a school history of reading problems, (b) those who had difficulties in all subjects and (c) those who had average performance in all subjects. We studied only children who were typically achieving or children with poor mathematics performance according to the results obtained from the administration of the BADYG Arithmetic subtest.

The children received all the word problems in three individual sessions of 20 minutes each. Subjects were tested individually in a quiet room. The order in which the problems were presented was counterbalanced. Each word problem was read to the participant, whose task it was to tell how he or she would solve the problem and carry out any actual arithmetic operations. Subjects were instructed to listen to the single auditory presentation of each problem; they were allowed to make notes while the examiner read each problem. No time limitations were imposed. The subjects were asked to solve 40 word problems, preceded by four practical problems to familiarize them with the task (for a description, see Jiménez & García, 1999).

Counters, paper and pencils were offered to the children by the examiner. Sentence length, syntactic complexity and vocabulary difficulty were controlled when the arithmetic word problems were designed. The quantity magnitude was also controlled because all word problems always included combinations of units and tens. Solutions to the word problems were considered correct when the child carried out counting procedures correctly and there was no operation error.

A reliability analysis was carried out on the different word problems, and the alpha coefficient was calculated for each category. The alpha for all categories was .93. In the Change problem it was .85. In the Combine problem it was .64. For the Equalize problem it was .77, and for Compare problem it was .80.

Instruments

Batería de Aptitudes Diferenciales y Generales (General and Differential Aptitudes Tests) (BADYG; Yusté, 1985). The BADYG Arithmetic subtest consists of a written section with increasingly difficult computations. Level 2 (ages 6 to 7) consists of 35 items, each of which has four alternative responses to assess basic addition and subtraction operations. Level 3 (ages 8 to 9) consists of 32 items, each of which has five alternative responses to assess calculation speed, numerical judgment, and operation in logical-numerical problems. A reliability analysis using the split-half procedure gave a coefficient result of .86 in Level 2 and .91 in Level 3, and the correlation between BADYG Arithmetic subtest and class grade was .53 for Level 2 and .44 for Level 3.

Test of intelligence. *The Wechsler Intelligence Scale for Children-Revised* (WISC-R) (Wechsler, 1989) was administered. In a reliability analysis using the split-half procedure for the Spanish revision of the WISC, the correlation coefficient (Spearman-Brown) was .93.

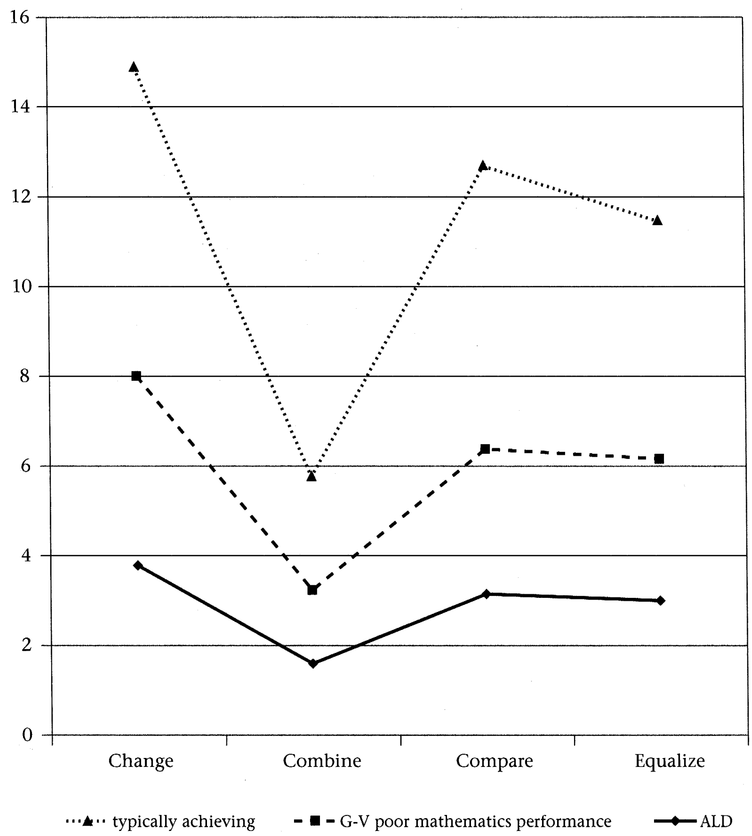
Arithmetic word problems. Two items were designed for each arithmetic word problem category and a total of 40 problems were used. Each of the arithmetic word problems describes a simple situation involving either addition or subtraction. The categories included Change, Combine, Equalize and Compare, which are representative of categorical schemes that several investigators (e.g., Carpenter & Moser, 1982) have used to analyze simple addition and subtraction problems. In addition to the various semantic relations, there are other ways in which the problems differ:

> In each kind of problem there are three items of information. In Change problems, the three items of information are the start, change, and result sets. Any of these can be found if the other two are given, yielding three different cases: the unknown may be the start, the change, or the result. Furthermore, the direction of change can either be an increase or a decrease, so there are a total of six kinds of Change problems. A similar set of variations exists for Compare problems, where the direction of difference may be more or less and the unknown quantity may be the amount of difference between the referent set and the compared set, or either of the two sets themselves. In Combine problems there are fewer possible variations: the unknown is either the combined set or one of the subsets. Equalizing problems usually restrict the unknown to the difference between the given quantity and the desired quantity, although a total of six variations are possible. (Riley et al., 1983, p. 161)

RESULTS

The mean full-scale IQ test of the children with ALD, G-V poor mathematics performance children and typical achievement children were 99.7, 89.3 and 110.7, respectively. The mean arithmetic achievement of the children with ALD, G-V poor mathematics performance and typical achievement children were 11.1, 13.4 and 28.3, respectively.

Figure 1. Counting strategies mean scores of the ALD, G-V and typical achievement students on different semantic structure word problem solutions.



Analyses of variance (ANOVAs) for one factor (typically achieving vs. ALD vs. G-V poor mathematics performance) and a Scheffé test were performed. When individual comparisons are reported as significant, it was $p < .05$. The F value for the various ANOVAs were as follows: Full Scale IQ, $F(147,2) = 59.3$, $p < .001$; BADYG Arithmetic subtest, $F(147,2) = 283.7$, $p < .001$; counting strategies to resolve Combination problems, $F(147,2) = 8{,}107$, $p < .0001$; counting strategies to resolve Comparison problems, $F(147,2) = 18{,}358$, $p < .0001$; counting strategies to resolve Change problems, $F(147,2) = 12{,}836$, $p < .0001$; counting strategies to resolve Equalizing problems, $F(147,2) = 10{,}624$, $p < .0001$; number facts strategies to resolve Combination problems, $F(147,2) = 22{,}393$, $p < .0001$; number facts strategies to resolve Comparison problems, $F(147,2) = 16{,}774$, $p < .0001$; number facts strategies to resolve Change problems, $F(147,2) = 20{,}244$, $p < .0001$; and number facts strategies to resolve Equalizing problems, $F(147,2) = 14{,}605$, $p < .0001$.

Differences were found between children with ALD and G-V poor mathematics performance on full-scale IQ. Children with ALD were significantly superior on the intelligence test. Individuals with average performance had significantly higher scores than students with ALD and those with G-V poor mathematics performance. No differences were found between children with ALD and G-V poor mathematics performance when counting strategies were used in Change, Combination, Comparison and Equalizing problems. However, individuals with average performance obtained significantly higher scores than children with ALD and those with G-V poor mathematics performance in the use of Counting to solve the four semantic categories of arithmetic word problems. Figure 1 shows the means of the counting strategies used to solve the word problems in the four semantic categories.

No differences were found between children with ALD and G-V poor mathematics performance in the use of number facts strategies in Change, Combination, Comparison and Equalizing problems. However, individuals with average performance had significantly higher scores than children with ALD and those with G-V poor mathematics performance in the use of number facts strategies to solve the four semantic categories of arithmetic word problems. Figure 2 ilustrates the means of the number facts strategies used to solve the word problems in the four semantic categories

In the use of modeling strategies, no differences were found between the groups. Table 1 includes the means and standard deviations of the strategies of modeling, counting and number facts used in SAWP in the four semantic categories for the three groups. Figure 3 shows the means of the modeling strategies used in the four semantic categories.

DISCUSSION

The aim of this study was to test whether the strategies used by children with low achievement in arithmetic and high IQ (discrepant) differ from those of children with low achievement and also low IQ (nondiscrepant) when solving arithmetic word problems. We compared the behavior of these two groups of children when solving word arithmetic problems during the execution phase, when the problem solver carries out the computations he or she needs in order to execute the plan

Figure 2. Number facts strategies mean scores of the ALD, G-V and typical achievement students on different semantic structure word problem solutions.

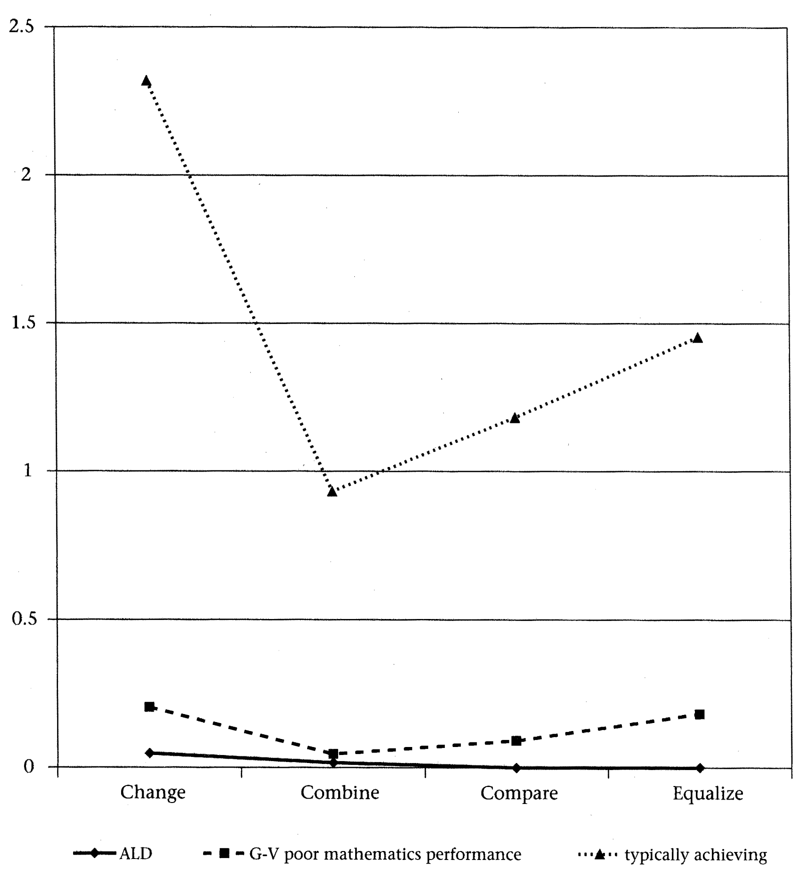
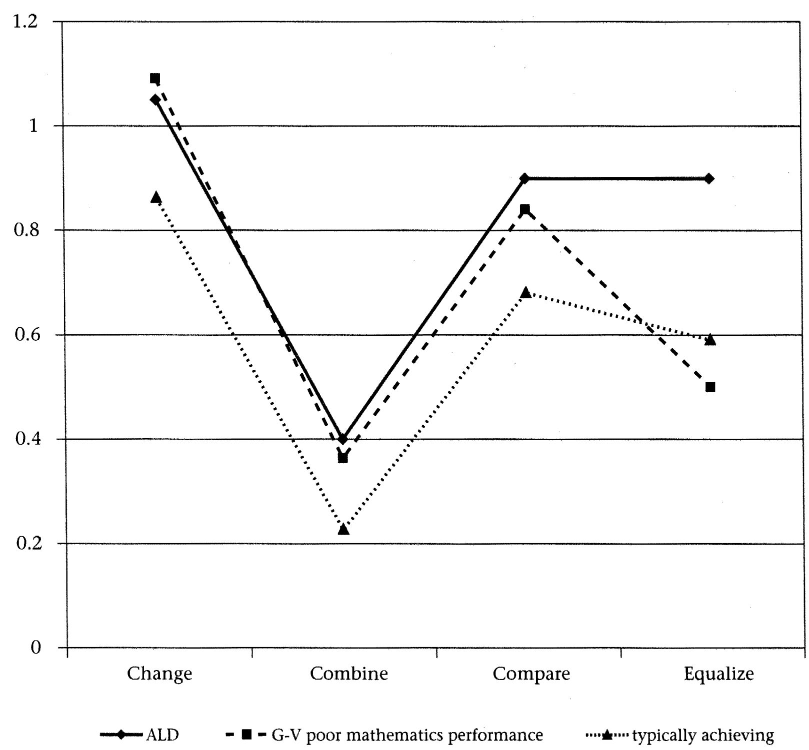


Figure 3. Modeling strategies mean scores of the ALD, G-V and typical achievement students on different semantic structure word problem solutions.



developed previously, and also compared them with the performance of typically achieving children.

Research in arithmetic learning disabilities suggests that children with learning disabilities differ from typically achieving children by using strategies that are less developed or are the same as those used by younger typically achieving children (Fleischner, Garnett, & Shepherd, 1982; Garnett & Fleischner, 1983; Geary, 1990; Geary & Brown, 1991; Geary et al., 1987; Goldman et al., 1988). Our results confirm these findings, as both the discrepant and the nondiscrepant children basically used less developed strategies than typically achieving children, such as counting and occasionally modeling, but not mental strategies that require the retrieval of number facts from long-term memory. Both groups used the same set of additive and subtractive strategies. The strategies most frequently used were counting for the addition "counting on from larger" and for the subtraction "counting up from given" and less frequently "counting down from." They depended on direct modeling by means of "counting all" for addition and "separating from" for subtraction, when the problems were more difficult. In contrast, typically achieving children used predominantly mental strategies to solve word problems, although counting strategies were often used also. Ostad (1997, 1999) found that fact-retrieval deficits in a sample of children with mathematics difficulties persisted throughout elementary school.

The finding that discrepant and nondiscrepant children do not differ substantially in their choice of strategies in SAWP reaffirms our belief that these two groups are not qualitatively different as the same cognitive processes underlie their performance. The use of less developed strategies to solve word problems has been explained in terms of immature or abnormal development of the representation of numerical associations in long-term memory (Garnett & Fleischner, 1983; Geary et al., 1987; Goldman et al., 1988). Furthermore, it has been suggested that a second factor contributing to learning difficulties in arithmetic is the existence of relatively poor working memory resources (Geary & Brown, 1991; Hitch & McAuley, 1991; Siegel & Ryan, 1989; Swanson, 1993, 1994). Our results confirm these findings, as poor achievers in arithmetic, whether discrepant or non-discrepant, obtained lower working memory scores than typically achieving children (see Jiménez & García, 1999).

This deficit in working memory means that poor achievers in arithmetic are not able to retain numerical information long enough to carry out the problem-solving operations. As a result, these children depend on strategies that are less memory-based. Also, their deficiency does not allow them to store retrievable number facts in long-term memory. This explains why children with difficulties do not depend on this numerical information, which they have not had the opportunity to store adequately (Geary et al., 1991). Their obvious familiarity with counting strategies does not appear to have helped them develop associations between a problem and its solution in long-term memory (Geary et al., 1991; Siegler, 1986). This finding is also consistent with Siegel's (1989) studies of reading, in which performance is explained by the same underlying cognitive processes, independently of IQ (Siegel, 1989, 1992; Stanovich, 1989). In this case, working memory would seem to be one of these processes (Geary & Brown 1991; Hitch & McAuley, 1991; Siegel & Ryan, 1989; Swanson, 1993, 1994).

It is important, however, to consider the relevance of other phases in mathematical problem solving (Mayer, 1985; Mayer et al., 1984) that involve other cognitive and metacognitive strategies that we did not allow for in this research, and that should be the subject of future studies, such as, error analysis in order to explain students' problems during the integration or planning phases.

In summary, we suggest that there are no reasons to think that individuals with high- and low-IQ poor mathematics performance differ in the cognitive processes underlying solving arithmetic word problems. Therefore, the use of the discrepancy criterion to differentiate between these subjects seems to be inadequate.

Table 1

Means and Standard Deviations of the ALD, G-V and Typical Achievement Students on Word Problem Solution Strategies by Semantic Structure

	Group					
	Arithmetic Learning Disabilities		G-V Poor Mathematics Performance		Typically Achieving	
	M	*SD*	*M*	*SD*	*M*	*SD*
Modeling Strategy						
Change	1.05	1.96	1.09	1.98	0.86	2.29
Combine	0.40	0.71	0.36	0.80	0.22	0.56
Compare	0.90	1.91	0.84	1.59	0.68	1.76
Equalize	0.90	1.60	0.50	1.21	0.59	1.67
Counting Strategy						
Change	3.78	2.81	4.22	2.89	6.88	3.99
Combine	1.60	1.26	1.63	1.25	2.54	1.33
Compare	3.15	2.71	3.22	2.57	6.38	3.51
Equalize	3.00	2.49	3.15	2.49	5.31	3.18
Number Facts Strategy						
Change	0.08	0.53	0.20	0.70	2.31	3.38
Combine	0.01	0.12	0.04	0.21	0.93	1.35
Compare	0.01	0.10	0.09	0.42	1.81	3.11
Equalize	0.01	0.12	0.18	0.78	1.45	2.50

REFERENCES

Ackerman, P. T., Anhalt, J. M., & Dykman, R. A. (1986). Arithmetic automatization failure in children with attention and reading disorders: Associations and sequelae. *Journal of Learning Disabilities, 19,* 222-232.

Badian, N. A. (1983). Dyscalculia and nonverbal disorders of learning. In H. R. Myklebust (Ed.), *Progress in learning disabilities,* Vol. 5 (pp. 235-264). New York: Grune & Stratton.

Carpenter, T. P., & Moser, J. M. (1982). The development of addition and subtraction problem-solving skills. In T. P. Carpenter, J. M. Moser, & T. A. Romberg (Eds.), *Addition and subtraction: A cognitive perspective* (pp. 9-24). Hillsdale, NJ: Lawrence Erlbaum Associates.

Carpenter, T. P., & Moser, J. M. (1983). The acquisition of addition and subtraction concepts. In R. Lesh & M. Landau (Eds.), *Acquisition of mathematical concepts and processes* (pp. 7-44). New York: Academic Press.

Carpenter, T. P., & Moser, J. M. (1984). The acquisition of addition and subtraction concepts in grades one through three. *Journal for Research in Mathematics Education, 15,* 179-202.

Carpenter, T. P., Hiebert, J., & Moser, J. M. (1981). The effect of problem structure on first-graders' initial solution processes for simple addition and subtraction problems. *Journal for Research in Mathematics Education, 12,* 27-39.

Cummins, D. D. (1991). Children's interpretations of arithmetic word problems. *Cognition and Instruction, 8,* 261-289.

Cummins, D. D., Kintsch, W., Reusser, K., & Weimer, R. (1988). The role of understanding in solving word problems, *Cognitive Psychology, 20,* 405-438.

De Corte, E., & Verschaffel, L. (1987). The effect of semantic structure on first graders' strategies for solving addition and subtraction word problems. *Journal for Research in Mathematics Education, 18,* 363-381.

Fleischner, J. E., Garnett, K., & Shepherd, M. J. (1982). Proficiency in arithmetic basic fact computation of learning disabled and nondisabled children. *Focus on Learning Problems in Mathematics, 4,* 47-56.

Garnett, K. (1992). Developing fluency with basic number facts: Intervention for students with learning disabilities. *Learning Disabilities Research and Practice, 7,* 210-216.

Garnett, K., & Fleischner, J. E. (1983). Automatization and basic fact performance of normal and learning disabled children. *Learning Disability Quarterly, 6,* 223-230.

Geary, D. C. (1990). A componential analysis of an early learning deficit in mathematics. *Journal of Experimental Child Psychology, 49,* 363-383.

Geary, D. C., & Brown, S. C. (1991). Cognitive addition: Strategy choice and speed-of-processing differences in gifted, normal, and mathematically disabled children. *Developmental Psychology, 27,* 398-406.

Geary, D. C., Brown, S. C., & Samaranayake, V. A. (1991). Cognitive addition: A short longitudinal study of strategy choice and speed of processing differences in normal and mathematically disabled children. *Developmental Psychology, 27,* 789-797.

Geary, D. C., Widaman, K. F., Little, T. D., & Cormier, P. (1987). Cognitive addition: Comparison of learning disabled and academically normal elementary school children. *Cognitive Development, 2,* 249-269.

Ginsburg, H. P. (1997). Mathematics learning disabilities: A view from developmental psychology. *Journal of Learning Disabilities, 30,* 20-33.

Goldman, S. R. (1989). Strategy instruction in mathematics. *Learning Disability Quarterly, 12,* 43-55.

Goldman, S. R., Pellegrino, J. W., & Mertz, D. L. (1988). Extended practice of basic addition facts: Strategy changes in learning disabled students. *Cognition and Instruction, 5,* 223-265.

Groen, G. J., & Parkman, J. M. (1972). A chronometric analysis of simple addition. *Psychological Review, 79,* 329-343.

Hegarty, M., Mayer, R. E., & Monk, C. A. (1995). Comprehension of arithmetic word problems: A comparison of successful and unsuccessful problem solvers. *Journal of Educational Psychology, 87,* 18-32.

Hegarty, M., Mayer, R. E., & Green, C. E. (1992). Comprehension of arithmetic word problems: Evidence from students' eye fixations. *Journal of Educational Psychology, 84,* 76-84.

Hiebert, J., Carpenter, T. P., & Moser, J. M. (1982). Cognitive development and children's solutions to verbal arithmetic problems. *Journal for Research in Mathematics Education, 13,* 83-98.

Hitch, G. H., & McAuley, E. (1991). Working memory in children with specific arithmetical learning difficulties. *British Journal of Psychology, 82,* 375-386.

Jaspers, M. W., & van Lieshout, E. C. (1994). Diagnosing wrong answers of children with learning disorders solving arithmetic word problems. *Computers in Human Behavior, 10,* 7-19.

Jiménez, J. E., & García, A. I. (1999). Is IQ-achievement discrepancy relevant in the definition of arithmetic learning disabilities? *Learning Disability Quarterly, 22,* 291-301.

Jiménez, J. E., & Rodrigo, M. (1994). Is it true that the differences in reading performance between students with and without LD cannot be explained by IQ? *Journal of Learning Disabilities, 27,* 155-163.

Jordan, N. C., & Hanich, L. B. (2000). Mathematical thinking in second-grade children with different forms of LD. *Journal of Learning Disabilities, 6,* 567-578.

Jordan, N. C., & Oettinger, T. (1997). Cognitive arithmetic and problem solving: A comparison of children with specific and general mathematics difficulties. *Journal of Learning Disabilities, 30,* 624-634, 684.

Kosc, L. (1974). Developmental dyscalculia. *Journal of Learning Disabilities, 7,* 164-177.

Mayer, R. E. (1986). Capacidad matemática [Mathematical ability]. Stenberg, R. J. (Ed.) *Las capacidades humanas. Un enfoque desde el procesamiento de la información* [Human abilities: An information processing approach (pp. 165-194). Barcelona, Spain: Labor.

Mayer, R. E., Larkin, J. H., & Kadane, J. B. (1984). A cognitive analysis of mathematical problem-solving ability. In J. R. Stenberg (Ed.), *Advances in psychology of human inteligence* (Vol. 2, pp. 231-273). Hillsdale, NJ: Erlbaum.

Mercer, C. D., & Miller, P. S. (1992). Teaching students with learning problems in math to acquire, understand, and apply basic math facts. *Remedial and Special Education, 13,* 19-35, 61.

Miller, P. S., & Mercer, C. D. (1997). Educational aspects of mathematics disabilities. *Journal of Learning Disabilities, 30,* 47-56.

Ostad, S. A. (1997). Developmental differences in addition strategies: A comparison of mathematically disabled and mathematically normal children. *British Journal of Educational Psychology, 67,* 345-357.

Ostad, S. A. (1998). Developmental differences in solving simple arithmetic word problems and simple number-fact problems: A comparison of mathematically normal and mathematically disabled children. *Mathematical Cognition, 4,* 1-20.

Ostad, S. A. (1999). Developmental progression of subtraction strategies: A comparison of mathematically normal and mathematically disabled children. *Mathematical Cognition, 4,* 1-20.

Parmer, R. S., Cawley, J. R., & Frazita, R. R. (1996). Word problem-solving by students with and without mild disabilities. *Exceptional Children, 62,* 415-429.

Riley, M. S., & Greeno, J. G. (1988). Developmental analysis of understanding language about quantities and of solving problems. *Cognition and Instruction, 5,* 49-101.

Riley, M. S., Greeno, J. G., & Heller, J. I. (1983). Development of children's problem-solving ability in arithmetic. In H. P. Ginsburg (Ed.), *The development of mathematical thinking* (pp. 153-196). New York: Academic Press.

Riviére, A. (1990). Problemas y dificultades en el aprendizaje de las matemáticas: una perspectiva cognitiva [Learning disabilities in mathematics: A cognitive approach]. En A. Marchesi, C. Coll, J. Palacios (Eds.) *Desarrollo psicológico y educación; III Necesidades educativas especiales y aprendizaje escolar* [Developmental psychology and education, III Special Educational Needs and school learning] (pp. 155-182). Madrid: Alianza Psicología.

Russell, R., & Ginsburg, H. (1984). Cognitive analysis of children's mathematics difficulties. *Cognition and Instruction, 1,* 217-244.

Siegel, L. S. (1989). IQ is irrelevant to the definition of learning disabilities. *Journal of Learning Disabilities, 22,* 469-486.

Siegel, L. S. (1992). An evaluation of the discrepancy definition of dyslexia. *Journal of Learning Disabilities, 25,* 618-629.

Siegel, L. S., & Ryan, E. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development, 60,* 973-980.

Siegler, R. S. (1986). Unities across domains in children's strategy choices. In M. Perlmutter (Ed.), *Perspectives for intellectual development: Minnesota symposia on child psychology* (Vol. 19, pp. 1-48). Hillsdale, NJ: Erlbaum.

Siegler, R. S., & Robinson, M. (1982). The development of numerical understandings. In H. Reese & L. P. Lipsitt (Eds.), *Advances in child development and behavior* (Vol. 16, pp. 241-312). San Diego, CA: Academic Press.

Stanovich, K. E. (1989). Has the learning field lost its intelligence? *Journal of Learning Disabilities, 22,* 487-492

Stanovich, K. E., & Siegel, L. S. (1994). The phenotypic performance profile of reading-disabled children: A regression based test of the phonological-core variable-difference model. *Journal of Educational Psychology, 86,* 1-30.

Swanson, H. L. (1993). Working memory in learning disability subgroups. *Journal of Experimental Child Psychology, 56,* 87-114.

Swanson, H. L. (1994). Short-term memory and working memory: Do both contribute to our understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities, 27,* 34-50.

Swanson, H. L., Cooney, J. B., & Brock, S. (1993). The influence of working memory and classification ability on children's problem solution. *Journal of Experimental Child Psychology, 55,* 374-395.

Toth, G., & Siegel, L. S. (1994). A critical evaluation of the IQ-achievement discrepancy based definition of dyslexia. In K. P. van den Bos, L. S. Siegel, D. J. Bakker, & D. L. Share (Eds.), *Current directions in dyslexia research* (pp. 45-70). Lisse, The Netherlands: Swets and Zeitlinger.

Yusté, C. (1985). *Batería de Aptitudes Diferenciales Generales* [Mental Abilities Test]. Madrid: Ciencias de la educación preescolar y especial.

Wechsler, D. (1989). *Escala de inteligencia de Wechsler para niños* [Wechsler Intelligence Scale for Children]. Madrid: TEA Ediciones, S.A.

Wynn, K. (1990). Children's understanding of counting. *Cognition, 36,* 155-193.

Correspondence concerning this article should be addressed to: Juan E. Jiménez González, Departamento de Psicología Evolutiva y de la Educación, Universidad de La Laguna, Campus de Guajara, 38200 Islas Canarias, España. Electronic mail may be sent to ejimenez@ull.es.