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Arithmetical difficulties and low arithmetic achievement: analysis of the underlying cognitive functioning

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Abstract

This study analyzed the cognitive functioning underlying arithmetical difficulties and explored the predictors of arithmetic achievement in the last three grades of Spanish Primary Education. For this purpose, a group of 165 students was selected and divided into three groups of arithmetic competence: Mathematical Learning Disability group (MLD, n = 27), Low Achieving group (LA, n = 39), and Typical Achieving group (TA, n = 99). Students were assessed in domain-general abilities (working memory and PASS cognitive processes), and numerical competence (counting and number processing) during the last two months of the academic year. Performance of children from the MLD group was significantly poorer than that of the LA group in writing dictated Arabic numbers (d = -0.88), reading written verbal numbers (d = -0.84), transcoding written verbal numbers to Arabic numbers (-0.75) and comprehension of place value (d = -0.69), as well as in simultaneous (d = -0.62) and successive (d = -0.59) coding. In addition, a specific developmental sequence was observed in both groups, the implications of which are discussed. Hierarchical regression analysis revealed simultaneous coding (β = .47, $t(155) = 6.18$, $p < .001$) and number processing (β = .23, $t(155) = 3.07$, $p < .01$) as specific predictors of arithmetical performance.

Keywords: arithmetic achievement, Primary Education, working memory, PASS processes, numerical competence

Arithmetical difficulties and low arithmetic achievement: analysis of the underlying cognitive functioning

The curricular area of arithmetic produces a high percentage of school failure and, alarmingly, the number of students who present math difficulties has increased significantly in recent years (Passolungui & Lanfranchi, 2012). Several recent studies (e.g., Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005) calculate a prevalence of mathematics learning disability (MLD) of between 3.6 and 9.8%, and an estimated rate of about 10 to 15% of low achieving (LA) students, who show milder but equally persistent difficulties (Mazzocco, 2007). In the Spanish context, the data of the 2012 Program for International Student Assessment (PISA) (OECD, 2013) confirm these data, estimating that 24% of the students present a low performance in mathematics. Of these, 7.8% do not even reach the required minimum level.

Mathematics is a high-level activity that, throughout the school curriculum, encompasses the mastery of aspects such as arithmetic, trigonometry, and geometry. This study focuses on a specific field: arithmetic achievement and, particularly, on analysis of the cognitive functioning underlying arithmetical difficulties. In order to establish the object of study, arithmetic is operationally defined as the skill to resolve arithmetic operations, retrieving facts and rules and correctly implementing the corresponding algorithms.

Arithmetic is introduced early in school, and its competence determines the mastery of other mathematical fields, and even access to higher studies or to future employability (Geary, 2011). Despite the exponential increase of research in the past twenty-five years, researchers still no not perfectly understand how arithmetic skills are acquired throughout the school years and which processes are linked to individual differences in arithmetical performance. Within this sphere, there are two opposite opinions. The first one associates arithmetical difficulties with a specific deficit in numerical representation (Butterworth, 2005). The second theoretical perspective has habitually focused on analyzing the relations between arithmetic and diverse basic cognitive mechanisms, such as working memory, processing and executive skills, among others (e.g., Fuchs et al., 2006).

This study draws from inclusive positions (e.g., Passolungui, Vercelloni, & Schadee, 2007) that have used domain-general abilities (e.g., working memory, planning, attention, and the processing system), as well as domain-specific abilities related to numerical competence (e.g., counting and number processing) as predictors. The involvement of domain-general abilities in the learning of curricular aspects like reading, writing, math, history, etc., seems undeniable. Also, in the case of mathematics, abilities like estimating, number comprehension, and the decimal number system or counting are precursors, from the developmental viewpoint, of subsequently acquired mathematical abilities like arithmetic, algebra, or problem solving. These domain-specific abilities have been shown to be capable of predicting arithmetic achievement at early educational levels.

Domain-general abilities

Working memory

During the past 30 years, many investigators in the field have used Baddeley and Hitch's (1974) model as cognitive support for mathematical achievement (e.g., Geary et al., 2009). However, as recent reviews have noted (e.g., Raghubar, Barnes, & Hecht, 2010), research of the relation between the working memory and difficulties is less extensive in children than in adults.

The literature has related the diverse components of the model to specific aspects of mathematical performance (Swanson, Jerman, & Zheng, 2008). The phonological loop seems to participate in counting (Imbo & Vandierendonck, 2006) and in calculation (De Smedt

Verschaffel & Ghesquière, 2009). The visuo-spatial sketchpad seems relevant for simple calculation (McKenzie, Bull, & Gray, 2003), algorithmic computation requiring visual and spatial knowledge (Trbovich & Lefevre, 2003), and arithmetic estimation (Geary; Hoard, Byrd-Craven, Nugent & Numtee, 2007). The central executive has been implicated in the coordination of diverse activities involving counting (McLean & Hitch, 1999) and solving arithmetic problems (Swanson et al., 2008).

The publication of various correlational works using longitudinal designs has provided evidence of the relevance of the central executive and the phonological loop of the working memory (e.g., Meyer, Salimpoor, Wu, Geary, & Menon, 2010) and of the mediating capacity of processing speed (e.g., Fuchs et al., 2006) in school children between first and third grade, where arithmetic achievement seems linked to phonological and executive processes of the working memory or with processing speed. A specific developmental pattern also is observed in this relationship. Thus, processing speed would be important at the first levels, mainly associated with counting, as a strategy for solving arithmetic tasks. If the speed is slow, there is a mismatch between the time needed to count and the decay of information in the working memory, which could lead to errors in problem solving (McKenzie et al, 2003).

Likewise, solving simple and complex arithmetic tasks requires the encoding and maintenance of the information represented phonologically in the working memory (Fuchs et al., 2006). Thus, as long as arithmetic facts are not automated, or when serious difficulties to implement the procedures persist, the importance of the phonological loop seems obvious.

The executive processes of memory seem to be related to arithmetic performance throughout early and primary education (Passolugui et al., 2007). This relationship may be due to novel demands or to the complexity of the arithmetic task and could involve maintaining the relevant information in the working memory, inhibiting irrelevant incoming information, or shifting the strategy that was being used (Miyake et al., 2000).

Lastly, many comparative studies on memory span tasks (i.e., counting span and backward digit span) have found differences between groups with difficulties and control groups. Passolungui and Mamarella (2012) recently found differences between MLD and LA groups in spatial memory tasks. Geary (2011) pointed out that children with MLD show deficits in all three working memory components, whereas the performance of children with LA is similar to that of controls. However, to date, conclusive results have not been reached in tasks assessing the central executive (e.g., van der Sluis, van der Leij, & de Jong, 2005) or, particularly, in tasks used to analyze the visuo-spatial sketchpad (e.g., Temple & Sherwood, 2002).

PASS cognitive processes

Das, Naglieri, and Kirby (1991) elaborated a cognitive processing theory that transcends the conceptualization of intelligence based on the IQ because of its limitations to identify and intervene in learning difficulties. They based their theory on Luria's (1966) three mental functioning units, redefining intelligence as a function of four basic psychological processes: Planning, Attention, Simultaneous Processing, and Successive Processing (PASS). This perspective of intelligence was operationalized through the Das-Naglieri: Cognitive Assessment System (D.N:CAS, Naglieri & Das, 1997). The authors used its scales and subtests as a system to detect individual differences, alterations, and difficulties and to support the formulation of an intervention system.

According to Das et al.(1994), planning is the process by which individuals determine, select, apply, monitor, and assess the possible solutions to problems, self-regulating their performance to achieve the desired goal. As noted by Naglieri and Das (2005), the crucial aspect of this construct, measured through the D.N:CAS, is that it places the assessed child in a novel situation for which he or she has not yet acquired a strategy. Recently, Best, Miller and Naglieri (2011) related the planning measures of the D.N:CAS to the working memory and, specifically, to the executive functions of updating, inhibition, and shifting proposed by Miyake et al. (2000), because the scale tasks require the inhibition of unnecessary information, maintenance and monitoring of relevant information, and shifting strategies when necessary.

The process of attention allows the individual to perform a focused cognitive activity, selective and sustained over time, attending to some stimuli and inhibiting others depending on the pursued goals (Das et al., 1994). The three D.N:CAS subtests focus on visual attention tasks that require the subjects to hold relevant information in the short-term memory and inhibit nonrelevant information.

In order to use the incoming information, individuals employ two cognitive processes: simultaneous processing, whereby the individual integrates stimuli in a perceptual or conceptual entirety, and successive processing, through which stimuli are integrated in a specific serial order (Naglieri & Das, 1997).

In simultaneous processing, the relations between the elements of incoming information are used to produce a single or integrated code (Naglieri & Das, 2005). This construct, analyzed through verbal and nonverbal tasks by the simultaneous scale of the D.N:CAS, has been conceptually related to visuo-spatial ability (Naglieri, Rojahn, & Matto, 2007) and empirically to tasks assessing the visuo-spatial sketchpad of the working memory (e.g., Cai, Li, & Deng, 2013)

Successive processing is needed to produce and store a set of sequentially ordered data, although the information may not have been presented sequentially. The only apparent relation in the information seems to be sequential or temporal. Successive coding originally takes up as much space in the working memory as there are units within the code (Das et al., 1994). The three successive processing measures presented in the D.N:CAS have been experimentally linked to traditional tests of the phonological loop in the working memory (e.g, Cai et al., 2013).

The literature has identified relations between measures of mathematical achievement and the PASS cognitive processes (Das et al., 1994), planning (e.g., Kroesbergen, Van Luit, Naglieri, Taddei, & Franchi, 2010), attention (e.g., Kroesbergen, van Luit, & Naglieri, 2003), simultaneous and successive processing (e.g., Iglesias-Sarmiento & Deaño, 2011).

The relation between planning and arithmetic has been established in 5th grade (Garofalo, 1986) and in 10th grade (Naglieri & Das, 1997). Warrick (1989) found predictive relations between achievement and attention in 3rd graders. Some recent investigations, foreign to this theoretical position, have found robust relations between lack of attention and performance of arithmetic tasks such as simple calculation, algorithmic calculation, and problem solving in 3rd and 4th grade (e.g., Fuchs et al., 2006).

Other studies have confirmed the importance of simultaneous processing in calculation and other mathematical tasks (e.g., Kroesbergen et al., 2003). Recently, Iglesias-Sarmiento and Deaño (2011) found significant relationships between all the PASS measures and mathematical achievement in the global analysis of the sample. However, only simultaneous and successive processing were significantly related to performance at all three educational levels studied (4th, 5th, and 6th grades of Primary Education). A noteworthy result of this study is that both processes moderately differentiated the MLD and LA groups. The results of Iglesias-Sarmiento and Deaño (2011) as well as those of Warrick (1989) also show that simultaneous processing is a predictor of mathematical achievement. It is important to note, however, that this model of results depends on the mathematical measures used and on the subjects' ability levels. The crucial point is that simultaneous processing seems to be involved whenever the task requires relating or integrating information (Deaño, 2000).

Numerical competence

In recent years, a series of investigations have reactivated the proposals of Butterworth (2005) about the influence of numerical competence in high-level mathematical ability, such as arithmetic. Among the tests that have been used to investigate numerical competence are counting and number processing tests.

For the past three decades, most research has focused on abilities related to solving simple arithmetic problems and their developmental progress (e.g., Geary, Hoard, Byrd-Craven & DeSoto, 2004). To some extent, authors agree that the development of basic academic arithmetical competences is reflected in the use of more mature problem-solving strategies and in the improvement of conceptual arithmetical comprehension and related domains such as counting. For instance, to achieve competent arithmetical development, children must progress from counting as a simple strategy for solving arithmetic problems to the direct retrieval of arithmetical data from memory. This requires the formal codes and algorithms provided by the cultural environment; for instance, they must learn to read and write numbers (verbal and written) and to transcode them from one notation to another. Lastly, they must assimilate the procedures needed to perform arithmetical operations (Temple & Sherwood, 2002).

Diverse studies have reported disabilities in number processing and counting comprehension tasks (e.g., Geary, 2011) in children with difficulties. Geary et al. (2009) found differences between achiever groups in tasks associated with numerical competence. The MLD and LA groups' performance was poorer than that of the typical achieving group (TA) in tasks related to numerical comprehension and number line estimation.

Number processing has been linked in several cross-sectional (e.g., Holloway & Ansari, 2010) and recent longitudinal studies (e.g., Vabinst, Ghesquière, & De Smedt, 2014) to subsequent arithmetic performance. In a study with 1st graders from Primary Education, Passolungui et al. (2007) found that numerical competence and, specifically, counting, were precursors of early mathematical learning. Vabinst et al. (2014) related number processing to the development of simple arithmetic.

From an integrative viewpoint, the developmental model of numerical cognition of von Aster and Shalev (2007) established that the development of numerical competence is only possible as a result of the support of general cognitive abilities (e.g., working memory, executive function) that allow the acquisition of the primary abilities of comparing and estimating—firstly, of the Arabic and verbal numerical system, and subsequently, of the representation of the numerical sequence in a mental number line. They also postulated that deficits in domain-general abilities or in the acquisition of numerical competence can lead to different types of arithmetic difficulties.

The model of von Aster and Shalev (2007) proposes four steps that are necessary for the acquisition of numerical competence. Step 1 leads to the development of the primary preverbal skill of comparing and estimating quantities. The verbal numerical and Arabic systems are developed in Steps 2 and 3, respectively. In Step 4, the representation of the sequence of numbers as a mental number line is produced. According to these authors, a failure in any step leads to a blockage at that point, with added difficulties at the next step. Some people with visuo-spatial difficulty could not acquire the first step, the central numerical system, essential for the development of numerical competence or preverbal primary skills. At Step 2, the names of the numbers are frequently learned phonologically, but without the meaning of numerical magnitude, which prevents transcoding and comprehension of the Arabic quantity in the following steps. When attentional control of the central executive is affected, this can affect the quantity-word association, generating difficulties with counting routines and storage strategies of numbers as well as with successions of spoken numbers. This also impairs access to Step 3 of the development of the quantity-number relation, which is acquired through numerical transcoding and syntax of the place value of the number. The last step allows identification of the ordinal place values of numbers from base ten and base hundred, favoring mental calculation.

Fuchs et al. (2010) extended the model of von Aster and Shalev (2007) to the development of arithmetic abilities, providing some new evidence. The authors noted that the relationship between domain-general abilities and numerical competence varies depending on the complexity of the arithmetic abilities involved. Significant relationships between numerical competence and the recall of addition and subtraction facts were found in their study with children aged 5 to 7. When more complex tasks (solving arithmetic problems) are introduced, domain-general abilities (working memory) were the unique predictors.

Ultimately, the current literature seems to move towards an integrative framework for the study of arithmetic difficulties that questions the unique contribution of domain-general and domain-specific abilities to the development of arithmetic. In any case, the contribution of different factors seems to depend on the type of arithmetic tasks used and on the developmental stage studied.

The present study

The present study selected 165 students attending the last three levels of Spanish Primary Education, who were classified into three groups of arithmetic competence (MLD, LA, and TA). The main goal of this study is to identify the domain-general (verbal memory, processing speed, planning, attention, simultaneous and successive processing) and domain-specific mechanisms (counting and number processing) that differentiate the performance of the group with severe difficulties (MLD) compared to the group with low arithmetic achievement (LA).

The second goal is to analyze the contribution of domain-general abilities and numerical competence to arithmetic achievement at this educational stage.

This study expands on the results of prior research in the following way: (1) Firstly, it uses a multidimensional approach based on the PASS theory, which can provide additional information to solve the puzzle of the cognitive functioning underlying arithmetic performance. Although some studies relate cognitive PASS processes to mathematics, no studies have been consistently carried out in the sphere of arithmetic. (2) Secondly, this same viewpoint is also a novel way to investigate the differences between subjects with MLD and LA, which Geary (2011) indicated could not be linked to intelligence, and that could be associated with deficits in working memory only for children with MLD and but not for children with LA. In this sense, the PASS model transcends the traditional view of intelligence and orients its explanation to how the subject processes and encodes information, rather than on the quantity of information he/she is capable of retaining. (3) Likewise, in our study, we investigate the influence of the domain-general processes concurrently with the domain-specific abilities (counting and number processing) that have been considered specific precursors of arithmetic performance in some investigations carried out with kindergarten children. (4) Lastly, the study expands on some of the studies of children with MLD and LA, using a greater number of cognitive and numerical tasks and interpreting them from an integrative approach.

Method

Participants

The sample of this study was selected from a total group of 239 students, who represented all the school children between 4th and 6th grade in six Primary Education schools from the Galician community in Spain. Initial selection was done using the reports provided by school counselors and teachers, informing that none of the children displayed any developmental disorders or sensory or cognitive deficits, or special educational needs as a result of socio-cultural aspects. After initial screening, the parents' consent was requested. The final sample comprised a total of 165 students (88 boys and 77 girls).

Assignation of the children to the experimental conditions followed quantitative criteria recently proposed by the specialized literature (e.g., Mazzocco, 2007), on the basis of their performance on the Calculation Scale of the *Batería Neuropsicológica de Evaluación de las Habilidades Aritméticas [Neuropsychological Battery for the Assessment of Arithmetical Skills]* (BANEVHAR; Iglesias-Sarmiento & Deaño, 2011).

The operational criterion to select the 27 participants (9 from each educational level) of the MLD group was having a standard score equal to or lower than 80 on the scale, which represents a score below percentile 11. Their age ranged between 8 years and 11 months and 13 years and 3 months, with a mean age of 10 years and 9 months (SD = 1.49).

A total of 39 children (13 from each educational level) were selected for the LA group, with scores between percentiles 11 and 25. Their age ranged between 8 years and 10 months and 13 years and 2 months, mean age 10 years and 6 months (SD = 1.14).

Lastly, we assigned 99 children (33 from each educational level) to the TA group, based on a mathematical performance equal to or higher than percentile 26 on the scale. The age of this group ranged between 8 years and 8 months and 13 years and 2 months, mean age 10 years and 7 months (SD = 1.01).

The analyses conducted showed that the number of boys and girls in the arithmetical competence groups at any educational grade was not significantly different, χ^2 (1, N = 165) < 1. As shown by the factorial ANOVA, no significant differences in mean age were found when the three groups of mathematical competence were considered conjointly (p > .05). Significant differences were found between the mean ages of the diverse educational levels, $F(2, 156) = 251.36$, $p < .001$, $\eta^2 = .76$. Lastly, the factorial ANOVA yielded no significant interaction between arithmetical competence and educational level with regard to mean age ($p > .05$).

Measures

Arithmetic achievement

The Calculation Scale of the BANEVHAR (Iglesias-Sarmiento & Deaño, 2011) was applied to assess the children's arithmetical competence. This scale provides a final standard score (100, 15) related to children's educational level. The reliability index, calculated for the normative sample with the split-half method and Spearman-Brown correction, was .84 (Iglesias-Sarmiento & Deaño, 2011).

The scale, standardized for the second half of Primary Education, is made up of two tasks of *Operational Processing,* which assess comprehension of visual and oral signals; four tasks of *Mental Arithmetic*; and four tasks of *Written Arithmetic.* These tasks assess the retrieval of data, rules, and procedures of the four arithmetical operations.

In operational processing tasks, the name of the operation (e.g., multiplication) is presented visually and orally. Then, an arithmetic problem with simple digits is dictated, and the subject is asked to indicate whether the problem corresponds to the previously presented operation. Mental arithmetic tasks examine the recall of arithmetic facts and rules. The problems are presented verbally by the evaluator, and the child answers aloud. Addition, subtraction, multiplication, and division are tested separately with a varying number of items for each task: 23 for addition (e.g., 7 + 8), 24 for subtraction (e.g., 9 - 4) and multiplication (e.g., 8 x 7), and 26 for division (e.g., 16/8). The written arithmetic tasks are paper-and-pencil tests presented in the form of calculations in Arabic notation, and the children must write their answers directly in the same notation. Addition, subtraction, multiplication, and division are tested through 7 different tasks for each operation (e.g., 704 + 293; 2783 – 1899; 618 x 57; 5076/54).

Working memory

Processing speed. Processing speed was assessed through the results of the *Seeking Numbers* subtest of the Attention Scale of the D.N: CAS (Naglieri & Das, 1997). This individual test is carried out under time pressure. Participants must seek and underline all the digits with the same format (1 2 3 4 5 6), which are presented on a page divided into 15 rows with 14 numbers per row. The reliability index for this test, calculated using the test-retest method, was .84.

Memory Span. The Digit Tests of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974; Spanish version, 1993) were used to analyze memory span. In the Spanish adaptation of the task, *Digit Span Forward,* series of numbers are presented out loud, at a rate of one per second (5 2 1 7 9 3), and the children must repeat them. Two series are presented for each element. The length of each element varies between 3 and 9 digits. This test was used to measure the storage capacity of the phonological loop. In this study, Cronbach's alpha for this task was .59.

In the *Digit Backward* test, used to assess the central executive, the length of each element varies between 2 and 8 items (8 3 5 2 9 4 1). In this case, the children are asked to repeat the numbers in reverse order. In this study, Cronbach's alpha for this task was .62.

PASS Processes

The Spanish adaptation of the D.N:CAS (Naglieri & Das, 1997) battery was used to assess planning, attention, and simultaneous and successive processing. All the scales provide a final standard score (100, 15). The reliabilities of the D.N:CAS for the Spanish sample (Deaño, Alfonso, & Fernández, 2006) for each of the scales were: .90 (Planning), .89 (Attention), .92 (Simultaneous Processing), and .91 (Successive Processing). The model was assessed through various goodness-of-fit and incremental indexes that yielded values of over .90 for the goodness-of-fit index (GFI) and the adjusted goodness-of-fit index (AGFI), and a root mean square residual (RMSR) value lower than .10. These indexes indicate a good fit of the PASS model to the data for each one of the age groups assessed.

Planning. The *Planning* subtests present tasks requiring the children to make decisions in order to solve them. The Planning subtests require the children to elaborate an action plan, assess its utility, control its effectiveness, correct or reject an old plan if the task requires a change, and control impulsive performance. In the *Matching Numbers* subtest, children are asked to underline the two numbers in each row that are the same. There are 8 rows per page, and each row has 6 numbers. The final score is based on the combination of the time spent resolving the task and the number of hits. In the *Planned Codes* subtest, each page contains a distinct set of codes arranged in seven rows and eight columns, with aa legend at the top of each page showing how letters relate to simple codes (e.g., A = OX; B = XX; C = OO). Children should fill in the appropriate codes in empty boxes beneath each letter. The final score combines the hits and the time spent solving the task. In the last subtest, *Planned Connections*, the first six items require children to connect sequences of numbers (e.g., 1-2-3-4-5) appearing in a quasi-random order on a page in sequential order. The last two items require children to connect both numbers and letters (e.g., 1-

A, 2-B, 3-C) in serial order, alternating between numbers and letters. The final score is a combination of the number of hits and the total time spent completing the tasks.

Attention. In the Attention subtests, children must use focal attention to detect a specific stimulus and avoid responding to irrelevant stimuli. *Expressive Attention* is a Stroop task in which the children are asked to read the color words presented in quasi-random order. Next, they name the colors of a series of rectangles. Finally, the words of various colors are printed in a different color ink than the colors the words name. The children are asked to name the color ink the word is printed in, rather than to read the word. The final score refers only to the last page and is a combination of the number of hits and the time spent solving the task. *Number Detection* measures selectiveness and the capacity to resist distraction. The children should detect specific numbers on a page containing many distracters. Each item consists of rows of numbers that contain the same numbers as those of the model and distractors (numbers that do not correspond to those at the top of the page). The children's task consists of finding and underlining the numbers that correspond to those of the model at the top of the page. The score of this test is the combination of accuracy (hits - false detections) and the time spent on the task. In the third subtest, *Receptive Attention*, the children's task involves recognition of physically identical (e.g., T T, but not T t) and lexically similar pairs of letters (e.g., A a, but not A b). Here also, the final score is a combination of detection accuracy and the time spent on the task.

Simultaneous Processing. This scale includes tasks requiring perception of the parts of a Gestalt, comprehension of logical-grammatical relations, and synthesis of the parts in integrated groups, using both verbal and nonverbal content. Children are required to perceive objects as a group and to interrelate separate elements into a whole through the examination of stimuli during the activity or through recall of the stimuli. In the *Nonverbal Matrixes* subtest, children are required to decode the relationships among the parts of the item. This subtest uses the standard progressive matrices format, varying from simple patterns to more complex patterns like the 3x3 matrices. The child must choose from 6 options the one that occupies the space not covered in the presented item. The score is the number of hits. *Verbal Spatial Relations* requires comprehension of logical and grammatical descriptions of spatial relationships. The child's task is to choose, from 6 options, the drawing that correctly answers the question read by the evaluator and presented in written form at the bottom of each page of stimuli. The final score corresponds to the number of hits. In the third subtest, *Figure Memory*, the child is shown a stimulus-figure for 5 seconds. The child then must reproduce the same figure, which is embedded within a more complex drawing on the response page, by tracing all the lines of the figure. The final score is the number of hits.

Successive Processing. The subtests of this scale involve working with things in a specific serial order. Perception of stimuli in sequence and the formation of sounds and movements in order are required in successive processing. In these subtests, children should either reproduce a sequence of independent stimuli or answer questions based on understanding of syntactic relationships (Das et al., 1994). In the first subtest, *Word Series*, the children must repeat a series of frequently used monosyllabic words in the same order as stated by the examiner (e.g., net - custard - train - honey - sea - flower-foot - steer). The number of words varies between 2 and 9. The final score is the number of hits obtained. *Sentence Repetition* requires the children to repeat orally presented phrases that contain some semantic conflict (e.g., the blue is yellowing). The final score is the number of correctly repeated sentences. In the last subtest, *Sentence Questions*, the children are required to respond to questions about the previous subtest. Successful completion requires having understood the implicit meaning of the phrase (e.g., the blue is yellowing. Who is yellowing?). The score is the number of correctly answered questions.

Numerical Competence

Counting. The basic skills of counting and seriating were analyzed from the results achieved in the Counting Scale of the BANEVHAR (Iglesias-Sarmiento & Deaño, 2011). The first part, *Basic Counting Comprehension*, includes two tasks in which the child is verbally requested to count aloud *forwards* (from 0 to 30) and *backwards* (from 30 to 0) by threes. The *Seriating* task requires the child to indicate verbally the numbers preceding and following the number presented (e.g., ? 345.609 ?). Lastly, a group of five tasks are presented involving verbal counting and counting images under timed conditions. A final standard score (100, 15) is obtained. The reliability index of the scale for the normative sample was .87 (Iglesias-Sarmiento & Deaño, 2011).

Number Processing. Comprehension/production of numbers in diverse notations (Arabic, verbal oral, and written) was analyzed using the results achieved on the Number Processing Scale of the BANEVHAR (Iglesias-Sarmiento & Deaño, 2011). Six groups of tasks were administered. The *Transcoding* subtest includes six tasks that represent all the possible conversions among notations. In the first task, *Arabic to Verbal*, an answer sheet with numbers written in the Arabic notation (e.g., 18026) is presented, and the child is asked to read them. In the *Spoken Verbal to Written Verbal* task, the evaluator orally dictates the numbers for the child to write on the response sheet in the form of written verbal numbers (e.g., sixteen). The *Spoken Verbal to Arabic* task is just like the previous one except that the child must write the numbers in Arabic notation (e.g., 37.403). In the fourth task, *Arabic to Written Verbal*, an answer sheet with Arabic digits (e.g., 56) is presented, and the child is asked to transform the digits into a numerical word (fifty-six). In the fifth task, *Written Verbal to Spoken Verbal*, a sheet with numerical words (e.g., six thousand seven hundred and thirty-seven) is presented, and the child is asked to read them. In the last task of *Written Verbal to Arabic*, numbers are presented in the form of written verbal numbers (e.g., thirty-three thousand and forty-six), and the child is asked to write them in Arabic notation (33.046). In the task of *Number Bisection,* the child has to provide in written form, as described in the legend, the number that comes between a pair of given numbers (e.g., 2010 [2020] 2030). The *Magnitude Comparison* task assesses numerical comprehension in the diverse notations through three subtests. Arabic numerals (e.g., 3077 vs. 3057) and verbal numbers in their verbal and written form (e.g., nine hundred eleven vs. nine hundred seventeen) are evaluated independently. The *Numerical Value Comprehension* test assesses processing of the complex structure of the number. For this purpose, bills with fixed values are given to the child (50.000, 10.000, 5.000, 2.000, 1.000, 500 and 100), and he is asked to assemble a certain amount with the fewest possible bills. The child must write down the number of bills used beside each quantity. The *Ordering Multidigit Numbers* task requires comprehension of the number as a stable sequence. The child is asked to establish the order of a series of 10 numbers with multi-digits (64.987, 320.213, 292, 597.901…). The final task of the scale, *Understanding Place Value of the Number*, assesses comprehension of the value corresponding to the position of a digit within a number. The child is requested in writing to break down the number into units, tens, hundreds etc. on tables in which the cells appear in random order. The difficulty of this test is progressive. The total scale provides a final standard score (100, 15). The reliability index of this scale, calculated with the Spearman-Brown split-half formula for the normative sample was .82 (Iglesias-Sarmiento & Deaño, 2011).

Procedure

Participants in this study were assessed individually in two sessions during the last two months of the academic year. Each child was assessed in a specially prepared room at the child's school, after receiving the corresponding permissions from the family and the educational authorities. We carried out two different sessions for the assessment of each child, in which we followed the explicit sequence established in most of the recent research in the field. In the first session, carried out during the last week of May, we applied the domain-general tests (D-N:CAS and the Digit tests of the WISC-R). The mathematical tasks were assessed in a subsequent session during the first week of June. The duration of each session was about 2 hours.

Data Analysis

The statistical analysis of the variables was carried out with the computer application Statistical Product and Service Solutions (SPSS) version 18.

Firstly, we calculated the descriptive statistics of each item. Subsequently, two orthogonal contrasts were conducted with the procedure followed by Geary et al. (2007, p. 1349) to analyze achievement group differences. As in these authors' study, the TA group was compared with the MLD and LA groups in the first analysis, and the MLD and LA groups were compared in the second analysis. In tasks in which the TA-MLD-LA contrast was significant but the MLD-LA contrast was nonsignificant, the cognitive deficits are considered to be similar for the MLD and LA groups. According to these authors, in the tasks in which both contrasts (TA-MLD-LA and MLD-LA) were significant, MLD cognitive deficits are considered to be either more severe or different from LA deficits. If the MLD-LA contrast was significant, a complementary analysis was performed to calculate the effect size (*d*) with the formula $(M^1 - M^2)/S_D$, where S_D is the standard deviation for the total sample and M1 is the means of the group with lower achievement.

Lastly, hierarchical regression analysis was used to analyze the contribution of the aggregates of variables—grouped according to their theoretical coherence—to arithmetic achievement. For this purpose, in Step one, the variables related to working memory (processing speed, digit span forward, digit span backward) were entered into the regression equation. Subsequently, the four scales assessing the PASS cognitive processes (planning, attention, simultaneous and successive processing) were entered to examine the global relations between cognitive functioning and arithmetic achievement. Lastly, the two variables analyzing numerical competence (counting and number processing) were entered to determine the influence of numerical variables on the relationships between the cognitive variables and arithmetical competence.

Results

The descriptive results, organized by achievement groups, are shown in Table 1.

<INSERT TABLE 1 HERE>

Achievement group contrasts

PASS processes

The TA-MLD-LA contrast was significant for Attention processes, $F(1, 162) = 5.25$, $p < .05$ (*d*s = 0.41 and 0.33), but the MLD-LA contrast was nonsignificant ($d = -0.08$). The TA-

MLD-LA contrast was significant in Simultaneous Processing, $F(1, 162) = 95.44$, $p < .001$ (*d*s = 1.55 and 0.93 for the contrasts with MLD and LA, respectively) and in Successive Processing, $F(1, 162) = 26.08$, $p = .012$ (*d*s = 1.01 and -0.41, for the contrasts with MLD and LA, respectively). The MLD-LA contrast was also significant for Simultaneous Processing ($d = -0.62$), and for Successive Processing ($d = -0.59$), thereby revealing a tendency in the groups. The TA-MLD-LA contrast was nonsignificant for Planning ($p > .05$)

Working memory

No statistically significant differences were found in either of the two contrasts for Processing Speed. For the phonological loop, the TA-MLD-LA contrast was significant, $F(1, 162) = 17.57$, $p <.001$ (*d*s = 0.8 and 0.46, for the contrasts with MLD and LA, respectively), but the MLD-LA contrast was nonsignificant ($d = -0.12$). For the central executive, the TA-MLD-LA contrast was also significant, $F(1, 162) = 6{,}25$, $p < .001$ (*d*s = 0.47 and 0.41, for the contrasts with MLD and LA, respectively), but the MLD-LA contrast was not. These contrasts showed that the TA group was different from the other two groups in phonological loop and central executive functioning. This difference favored the TA group but did not constitute a tendency in the groups with learning difficulties (MLD and LA), which were not statistically different from each other. The groups were not different from each other in Processing Speed.

Counting

The TA-MLD-LA contrast was significant for forward, $F(1, 162) = 5.54$, $p < .01$ (*d*s = 0.36 and 0.49), and backward counting, $F(1, 162) = 14.15$, $p < .001$ (*d*s = 0.52 and 0.83). The MLD-LA contrast was nonsignificant in both tasks. There were no significant differences between the LA and MLD groups in forward (d = -0.13) or backward counting (d = -0.31), although LA scored lower than MLD.

The TA-MLD-LA contrast was significant for seriation, $F(1, 162) = 8.95$, $p = .01$, but the MLD-LA contrast was nonsignificant. The TA group was significantly different in seriation from MLD and LA (ds = 0.57 and 0.36), but the latter groups were not different from each other.

Neither the TA-MLD-LA, nor the MLD-LA contrasts were significant for counting images. There were no significant differences between the TA group and MLD and LA in counting images ($p > .05$).

Number processing

The TA-MLD-LA contrast was significant for reading Arabic numbers, $F(1, 162) = 17.46$, $p < .01$ (ds = 0.88 and 0.27), but the MLD-LA contrast was nonsignificant. No significant differences were found in any of the contrasts for writing dictated numerical words or transcoding Arabic to written verbal numbers. Writing dictated Arabic numbers was significant, $F(1, 162) = 39.98$, $p < .001$ (ds = 1.25 and 0.37) in all the contrasts (d = -0.88 for MLD-LA). Reading written verbal numbers was also significant, $F(1, 162) = 23.10$, $p < .01$, in all the contrasts (d = -0.84 for MLD-LA), as was also the case for translation of verbal written to Arabic, $F(1, 162) = 30.846$, $p < .001$ (d = -0.75, for MLD vs. LA). The significant TA-MLD-LA contrasts reveal the performance tendency and the severity of the limitation in these three tasks. The TA group scored higher than MLD and LA in reading Arabic numbers (ds = 0.88 and 0.27) and writing dictated Arabic numbers (ds = 1.25 and 0.37), in reading written verbal numbers (ds = 1.04 and 0.2), and in transcoding written verbal numbers to Arabic numbers (ds = 1.1 and 0.36). The TA-MLD-LA contrast was significant for numerical bisection, $F(1, 162) = 18.87$, $p = .001$, but the MLD-LA contrast was not ($p > .05$). The TA group successfully wrote the number between the other two numbers provided, with sets of two to four digits. They performed better than the two groups with learning difficulties (*d*s = 0.88 and 0.37).

The TA-MLD-LA contrast was nonsignificant for the magnitude comparison of Arabic numbers, but it was significant for the magnitude comparison of written verbal numbers, $F(1, 162) = 25.25$, $p < .001$ (*d*s = 0.97 and 0.48), and of oral numbers, $F(1, 162) = 17.96$, $p < .001$ (*d*s = 0.80 and 0.47, respectively, for contrasts with MLD and LA). The MLD-LA contrast was nonsignificant for all three tasks of magnitude comparison. The TA group scored higher than MLD and LA in the magnitude comparison of written verbal and oral numbers. MLD and LA have similar deficits in these tasks. However, all three groups performed magnitude comparison of Arabic numbers equally well.

The TA-MLD-LA contrast was significant for *Comprehension of the numerical value*, $F(1, 162) = 36.61$, $p < .001$ (*d*s = -0.02 and 0.89 for the contrast with LA and MLD, respectively), but the MLD-LA contrast was nonsignificant. The performance of the MLD and LA groups was similar, but different from that of the TA group.

For the *Ordering multidigit numbers* task, the TA-MLD-LA contrast was significant, $F(1, 162) = 16.43$, $p < .001$ (*d*s = 0.77 and 0.43 for the contrast with LA and MLD, respectively), but the MLD-LA contrast was nonsignificant. The performance of MLD and LA was similar for ordering multidigit numbers, but different from that of the TA group.

In the *Understanding the place of the number* task, *s*ignificant differences were found both in the TA-MLD-LA contrast, $F(1, 162) = 27.5$, $p < .001$ (*d*s = 1.05 and 0.37 for the contrast with LA and MLD, respectively), and in the MLD-LA contrast (*d* = -0.68). This reveals a different tendency in the three groups. Comprehension of the place value was much more impaired in the MLD group than in the LA group.

Cognitive difficulties in students from the MLD group

Analyzed as a group, MLD displayed more severe difficulties in number processing than LA (writing dictated Arabic numbers, reading written verbal numbers or transcoding written verbal numbers to Arabic numbers). The MLD group also presented more severe alterations than the LA group in comprehension of place value. The MLD group also displayed notable difficulties in Simultaneous and Successive processing.

Analysis by educational grade makes other difficulties more obvious. In counting forwards, there was a significant difference between MLD and LA in 5th grade, $F(1, 52) = 7.35$, $p < .05$ ($d = -0.96$ for MLD-LA) and 6th grade ($d = -0.55$ for the MLD-LA contrast). In number processing of MLD and LA groups of 4th grade, significant differences were also found in magnitude comprehension of written verbal numbers, $F(1, 52) = 14.68$, $p < .05$, revealing a poorer performance for the MLD group ($d = -0.80$). This was also found for ordering multidigits, which, despite the level of significance, $F(1, 52) = 10.71$, $p < .05$, presented a $d = -0.74$ for the MLD-LA contrast, with the worse performance corresponding to MLD. The MLD-LA contrast was also significant in comprehension of place value, $F(1, 52) = 9.65$, $p < .05$, and ($d = -0.82$). In number processing in 6th grade, significant differences were observed between the MLD and LA groups, $F(1, 52) = 14{,}72$, $p < .05$, for comprehension of the numerical value ($d = 0.74$). In the working memory system, in 6th grade, the MLD-LA contrast was significant for the central executive, $F(1, 52) = 5.09$, $p =.001$ ($d = 0.83$). In this case, the LA group's performance was the worst. In the MLD-LA contrast in processing speed, $F(1, 52) = 4.34$, $p < .05$ ($d = -0.96$), the performance of MLD was the most impaired and clearly different from that of LA, but there were no differences between LA and TA.

Cognitive difficulties in LA students

Taken as a group, LA was less efficient, with a worse—albeit nonsignificant—performance than that of MLD in counting and seriation. The LA group performed better than MLD in transcoding tasks of reading Arabic numbers, transcoding Arabic to written verbal numbers, writing dictated Arabic numbers, transcoding reading Arabic numbers to written numbers, and from written verbal to Arabic. The LA group performed better in comprehension of place value and in simultaneous and successive processing and, in 5th grade, in attention.

In the analysis by grade level, LA has a worse performance than the MLD group in counting forwards (d = -0.96) in 5th grade and in counting backwards in 6th grade (d = -0.55). Moreover, in 6th grade, the LA sample, compared with the MLD group, showed a notable difficulty to process numerical value (d = -0.74) and in central executive (d = -0.82). That is, numerical value and central executive are both more impaired in the LA group. The processing speed of LA was higher (d = 0.96) than that of MLD, but no different from that of the TA group. Differences in LA by grade level were observed in counting, comprehension of numerical value, and central executive.

Regression analysis

In Table 2 are presented the results of the hierarchical regression analysis carried out. In Model 1, which only explains 18% of the variance, processing speed, $\beta = -.19$, $t(161) = -2.70$, $p < .05$, and the phonological loop, $\beta = .32$, $t(161) = 4.12$, $p < .001$, are used as predictors of arithmetic achievement. The results of Model 2, which explains 46.6% of the variance, point to simultaneous processing as the unique cognitive predictor of arithmetic achievement, $\beta = .56$, $t(157) = 7.76$, $p < .001$. The introduction of the numerical variables in Model 3, which accounts for 50% of the variance, indicates that simultaneous processing, $\beta = .47$, $t(155) = 6.18$, $p < .001$, and numerical competence, β= .23, $t(155) = 3.07$, $p < .01$, both contribute to the prediction of arithmetic achievement.

<INSERT TABLE 2 HERE>

Discussion

The initial purpose of this investigation was to analyze the domain-general and domain-specific abilities that contribute to arithmetic achievement, according to the groups established, in order to determine group similarities and differences and to establish the predictors of arithmetic achievement. The use of criteria like those adopted herein allows us to determine differential mechanisms between the two groups of students with difficulties (MLD and LA). Lastly, simultaneous processing and number processing emerged as specific predictors of arithmetic achievement.

Cognitive function and arithmetic difficulties

The first goal of this study was to identify the domain-general and domain-specific mechanisms that differentiate the performance of the group with severe difficulties (MLD) compared to the group with low arithmetic achievement (LA).

The results reveal a pattern of lower performance for the groups with difficulties (MLD and LA) than for the TA group. In the case of the MLD and LA groups, the discrimination between the groups was established in the number processing tasks (comprehension of the number and of the decimal system) and in the cognitive processes of simultaneous and successive information encoding. The worst performance is observed in simultaneous processing.

These results confirm the importance of encoding as a differentiating element between the groups with difficulties (e.g., Kroesbergen et al., 2003), extending to other educational levels Geary et al.'s (2009) results regarding the poorer performance of children with difficulties compared to controls in numerical competence tasks. In relation to numerical competence, our study focused on the differences between the groups with MLD and LA in number processing in Arabic and verbal formats and on their difficulties to understand the decimal number system, aspects that have not been addressed in previous research.

Although the relationship between cognitive deficits and numerical competence shown by children with difficulties is not fully understood, there are theoretical proposals and empirical findings that link them to visuo-spatial abilities (e.g., Watters & English, 1995; Zorzi, Prifit, & Umiltá, 2002). This study has examined these abilities in simultaneous format, so the results could be interpreted in the sense that simultaneous processing differentiates the MLD performance level in these tasks from the LA level. These two groups have different levels of cognitive numerical performance, which could be determined by their simultaneous processing. We observed the presence of a visuo-spatial deficit that could contribute to transcoding and conceptual numerical comprehension at different levels for MLD and LA (e.g., Watters & English, 1995). Simultaneous codes are needed to recode numbers and to convey a numerical quantity to each one (Deaño, 2000).

When grade level was considered, another group difference emerged, showing that children in the MLD and LA groups present combinations of general and numerical deficits. In 4th grade, TA performance in practically all the tasks is different from that of the other two groups. In 5th grade, although the differences are notably reduced in transcoding, place value comprehension, and successive processing tasks, there are still differences in counting forward, attention, and simultaneous processing. In spite of the learning experiences throughout school years, in 6th grade, the two groups with difficulties have still not improved their performance of some transcoding tasks (i.e., writing dictated Arabic numbers and transcoding from written verbal to Arabic), compared with the TA group. Specifically, MLD also has problems with tasks of magnitude comprehension of written verbal numbers, ordering multidigits, and comprehension of place value. In contrast, LA has difficulties with counting, comprehension of place value, and the central executive. In this sense, the two groups are different, and in this case, in different ways. The difference is not in their level of performance itself, but rather it seems to come from domain-general abilities that support task performance when tasks are complex or not automated.

The MLD group improves its performance level in 5th and 6th grade in comparison with the TA group. Nevertheless, their problems are still mainly related to simultaneous processing. In 6th grade, the MLD group's phonological component of the working memory is no different from that of LA, but the central executive seems to perform much better in the MLD group.

In contrast, in 6th grade, the LA group has more difficulties to represent the number, but for a different reason than the MLD group. In 6th grade, there were no significant differences between the two groups in encoding. The MLD difficulties are basically visuo-spatial, unitary comprehension of the units, base ten, and base hundred. The characteristic LA profile from an early age (low score in selective attention, good level of processing speed, and difficulties in counting) supports the presence of noninhibition of the central executive by attentional control, an aspect that Geary (2011) has pointed to as the core of the difficulties shown by children with LA, and which recent literature has linked to the central executive (e.g., Best et al., 2011).

A possible explanation of these differences may be found in the development of the working memory. The phonological loop improves from age 6 until adolescence, and other executive functions improve substantially at age 11 and continue their development for almost two more decades (e.g., Gathercole & Alloway, 2008). In spite of this evolution, the phonological loop and the capacity of inhibition are present in early childhood (Davidson, Amso, Anderson, & Diamond, 2006).

Von Aster and Shalev's (2007) developmental model of the acquisition of numerical competence provides an integrative view. This model seems to support the existence of these two groups with different developmental pathways. According to this formulation, the MLD group would achieve the representation of numerical quantity through possible early difficulties that progressively condition spatial number achievement, resolving these situations in many cases. In contrast, the LA group also achieves numerical competence, but it may begin to encounter difficulties at later steps of the model, in the verbal counting system, for example. It is as though their difficulties increase as the representation of knowledge increases, and the combination and their working memory do not facilitate the ordinal elaboration of numerical competence.

Cognitive predictors

The second goal of the study was to analyze the contribution of domain-general abilities and numerical competence to arithmetic achievement at this educational stage. The results of our study indicate that, in contrast to the reports in the literature (e.g., Meyer et al., 2010), the working memory components, evaluated with classical memory span tests, do not emerge as sole predictors of arithmetic performance when other cognitive variables are concurrently taken into account. The phonological loop and processing speed emerge—albeit weakly—as predictors of achievement when analyzing other variables separately. In addition, the results point to simultaneous processing as a predictor of arithmetic skills. Thus, the hypothesis that simultaneous processing alterations may underlie the difficulties of children who perform worse than their peers in numerical and arithmetic tasks gains strength, thereby providing support to the results of some authors in the area of the PASS theory (e.g., Kroesbergen et al., 2003), or relating it to visuo-spatial aspects of working memory (e.g., van der Sluis et al., 2005). Lastly, our study identifies number processing as a specific predictor of arithmetic achievement. These data confirm and extend beyond the early school years the capacity of numerical competence to predict subsequent mathematical achievement (e.g., Holloway & Ansari, 2010).

Summing up, our findings indicate that the main differences between the two groups with learning problems, analyzed conjointly, are found in numerical competence (knowledge of the number and of the decimal number system) and in the cognitive encoding system (simultaneous and successive processing). Both groups use these skills, but in a different way. The LA group showed increased competence in their use compared with the group with MLD. Also, some developmental progress of the groups was observed in the studied educational grade levels, but this should be confirmed through longitudinal studies. Likewise, in our study, simultaneous processing and number processing emerge as predictors of arithmetic achievement.

The tests employed could produce differences with regard to other studies. In this sense, the results of this investigation should be interpreted in the light of the reliability and validity of the instruments used, and the findings should be limited to the educational levels and ages selected. Moreover, it should be taken into account that, in this study, we did not specifically investigate the visuo-spatial aspects of the working memory. However, it should be noted that we analyzed visuo-spatial performance as aspects linked to simultaneous processing. These aspects should be taken into account for future investigations.

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TABLES

Table 1

Descriptive Statistics

Construct	*Measure*	*Group* (*n* = 165) *M (SD)*	MLD (n = 27) *M (SD)*	LA (n = 33) *M (SD)*	TA (n = 99) *M (SD)*
Arithmetic	Standard score	99.61 (16.98)	76.11 (5.22)	88.62 (2.73)	110.34 (12.47)
PASS	Planning	95.29 (14.03)	89.26 (17.52)	95.59 (11.52)	96.82 (13.57)
	Attention	93.42 (13.79)	89.70 (16.10)	90.77 (9.68)	95.47 (14.23)
	Simultaneous Processing	96.75 (14.48)	81.19 (10.48)	90.21 (9.73)	103.58 (12.41)
	Successive Processing	96.85 (14.11)	86.30 (15.12)	94.69 (13.55)	100.58 (12.44)
Working Memory	Processing Speed	94.24 (29.56)	96.15 (32.69)	94.69 (13.56)	92.16 (28.11)
	Digit Span Forward	6.29 (1.98)	5.19 (1.57)	5.85 (1.67)	6.77 (2.04)
	Digit Span Backward	4.36 (1.56)	3,9 (1.00)	4.00 (1.57)	4.64 (1.69)
Counting	Standard score	99.86 (15.28)	93.37 (12.30)	93.62 (14.42)	104.09 (14.98)
	Counting Forwards	10.08 (1.82)	9.74 (2.46)	9.51 (2.00)	10.40 (1.46)
	Counting Backwards	8.94 (3.21)	8.19 (3.64)	7.18 (3.52)	9.85 (2.58)
	Seriation	9.46 (1.00)	9.07 (1.71)	9.28 (0.94)	9.64 (0.68)
	Counting Images	13.20 (6.01)	13.81 (5.07)	13.83 (7.51)	12.78 (5.58)
Number Processing	Standard score	101.08 (14.91)	87.41 (12.99)	96.10 (12.63)	106.78 (13.08)
	Arabic to Verbal	13.70 (0.94)	13.07 (1.66)	13.64 (1.06)	13.90 (0.39)
	Spoken Verbal to Written Verbal	9.31 (1.24)	9.11 (1.65)	9.44 (1.07)	9.32 (1.18)
	Spoken Verbal to Arabic	9.43 (1.22)	8.26 (2.05)	9.33 (1.13)	9.79 (0.60)
	Arabic to Written Verbal	9.29 (1.30)	9.44 (1.42)	9.18 (1.45)	9.29 (1.20)
	Written Verbal to Spoken Verbal	9.76 (0.61)	9.26 (1.13)	9.77 (0.48)	9.89 (0.32)
	Written Verbal to Arabic	8.68 (1.64)	7.30 (2.30)	8.54 (1.50)	9.12 (1.21)
	Numerical Bisection	4.10 (1.30)	3.26 (1.85)	3.92 (1.36)	4.40 (0.94)
	Comprehension of Arabic Numerals	8.87 (0.37)	8.81 (0.40)	8.82 (0.45)	8.91 (0.32)

Comprehension of Spoken Verbal Numerals	8.81 (1.33)	7.89 (1.91)	8.54 (1.19)	9.17 (1.02)
Comprehension of Written Verbal Numerals	9.31 (1.15)	8.67 (1.39)	9.05 (1.56)	9.59 (0.74)
Numerical Value Comprehension	3.07 (1.69)	2.22 (1.72)	2.00 (1.70)	3.72 (1.34)
Ordering Multidigit Numbers	8.73 (2.42)	7.41 (3.30)	8.26 (2.76)	9.29 (1.75)
Understanding Place Value	5.85 (2.02)	4.26 (2.47)	5.64 (2.28)	6.38 (1.47)

Table 2

Hierarchical Regression Analysis: Predictors of Arithmetic Achievement

Variable	R^2	ΔR^2	□□
Model 1	.18		
Processing Speed			-.19**
Digit Span Forward			.32***
Digit Span Backward			.14
Model 2	.466	.286	
Processing Speed			-.09
Digit Span Forward			.13
Digit Span Backward			.05
Planning			.07
Attention			.01
Simultaneous Processing			.56***
Successive Processing			.03
Model 3	.50	.034	
Processing Speed			-.06
Digit Span Forward			.10
Digit Span Backward			.01
Planning			.07
Attention			-.02
Simultaneous Processing			.47***
Successive Processing			.02
Counting			.01
Number Processing			.23**

Note: $*p < .05$. $**p < .01$. $***p < .0001$.