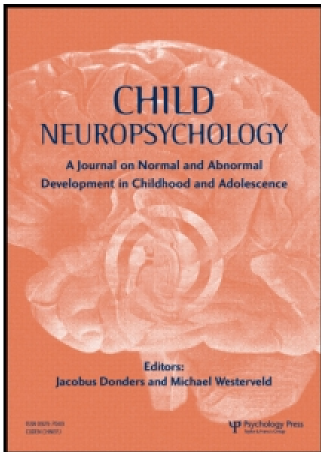

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Gender Differences and Cognitive Correlates of Mathematical Skills in School-Aged Children

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GENDER DIFFERENCES AND COGNITIVE CORRELATES OF MATHEMATICAL SKILLS IN SCHOOL-AGED CHILDREN

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Published information concerning the influence of gender on mathematical ability tests has been controversial. The present study examines the performance of school-aged boys and girls from two age groups on several mathematical tasks and analyzes the predictive value of a verbal fluency test and a spatial test on those mathematical tasks. More specifically, our research attempts to answer the following two questions: (1) Are gender differences in mathematical test performance among children interrelated with age and (2) do verbal and spatial nonmathematical tests mediate gender effects on mathematical test performance? Two hundred and seventy-eight 7- to 10-year-old children and 248 13- to 16-year-olds were selected from schools in Colombia and Mexico (231 boys and 295 girls). The age effect was found to be significant for all measures, with scores improving with age. Results showed that boys and girls in both age groups scored similarly in most subtests, but that differences emerged in the performance of mental mathematical operations and in resolving arithmetical problems. In the latter – but not in mental math – older boys outperformed older girls, whereas no gender differences were observed in the younger groups. After controlling for age, it was found that the spatial test was, indeed, a significant mediator of gender effects, while the verbal task was not.

Keywords: ***Mathematical skills; Gender; Development of calculation abilities; Math skills.***

Research on gender differences in mathematical test performance has been controversial. Traditionally, males have been considered to do better than females on mathematical achievement tests (e.g., Campbell, 2005; Hyde, Fennema, & Lamon, 1990; Royer, Tronsky, Chan, Jackson, & Marchant, 1999), though more recent reviews argue for similarities between the genders (e.g., Hyde, 2005). Although the bases underlying gender differences in mathematical performance are not yet fully understood (Ackerman, 2006; Imbo & Vandierendonck, 2007; Kaufmann & Nuerk, 2005; Spelke, 2005), age seems to play a role, since the most marked differences in mathematical test performance are usually reported among adolescents and adults (Hyde et al., 1990; Mullis, Martin, Fierros,

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Goldberg, & Stemler, 2000; Willingham & Cole, 1997). The extent of these differences among elementary school children is not yet altogether clear (Hyde et al., 1990).

This study examines the performance of school-aged boys and girls from two age groups on several mathematical tasks (knowledge of numbers, arithmetical operations, and worded arithmetical problems), and the predictive value of two neuropsychological tests — one verbal, one nonverbal — on these mathematical tasks. More specifically, this study was designed to answer two basic questions: (1) Are gender differences in children's mathematical test performance interrelated with age, and (2) do a verbal and a visuospatial nonmathematical test moderate gender differences in mathematical test performance?

The first question focuses on the influence of age on gender differences in mathematical test performance in school-aged children. Such differences in mathematical skills (e.g., Benbow, Libinski, Shea, & Eftekhari-Sanjani, 2000; Benbow & Stanley, 1983; Klein & Starkey, 1988) are not distributed evenly across age groups (e.g., Royer et al., 1999). For example, in their meta-analysis Hyde et al. (1990) reviewed the magnitude of gender differences using 254 effect sizes. They found no differences between elementary school boys and girls in the area of problem solving, but moderate gender differences that favored males at the high school and college levels. Similarly, substantial gender differences in the level of achievement in mathematics among students in middle school and high school compared to elementary school have been reported by Mullis et al. (2000) and Willingham and Cole (1997). The gap between boys and girls seems to increase in high school, where by the 12th grade males show very significant advantages over females of the same age in mathematical achievement tests (Willingham & Cole, 1997; Mullis et al., 2000). Moreover, among U.S. teenagers, more boys than girls are found in the upper reaches of the SAT-M (Scholastic Aptitude Test-Mathematics). For example, the National Average SAT-M scores in 2007 were 533 for boys and 499 for girls (College Board, 2008). According to these general results from the SAT-M (which tests numbers and operations, algebra and functions, geometry, statistics, probability, and data analysis), the average difference between boys and girls is about 7%. The largest gender differences in mathematical test performance have been found in selected populations of gifted participants, where males outperform females by about half a standard deviation (Benbow, 1988; Benbow & Stanley, 1983; Stanley, 1994). The magnitude of the gender difference favoring males increases as sample groups are selected according to higher math ability (Hyde et al., 1990). Finally, gender differences in mathematical reasoning among intellectually gifted children have been reported from as early as the second grade (Mills, Ablard, & Stumpf, 1993).

Several studies have analyzed the early development of mathematical skills in normal populations (e.g., Butterworth, 1999, 2005; Campbell, 2005; Donlan, 1998; Klein & Starkey, 1988) and distinguished different stages in the development of numerical knowledge (Butterworth, 1999, 2005; Kaufmann & Nuerk, 2005). Research focused on the development of numerosity and the understanding of numbers during infancy and the preschool years has not demonstrated any gender differences (for a review, see Spelke, 2005). Some studies, however, have reported such differences among preschool children on certain tasks that influence numerical/arithmetical performance, such as spatial transformation tasks (Levine, Huttenlocher, Taylor, & Langrok, 1999), in which boys consistently outperform girls.

Several hypotheses to account for gender differences in mathematical skills have been proposed. For instance, Geary (1996) suggests that these differences appear to be a consequence of the greater elaboration of the cognitive systems that support navigation in three-dimensional space in males as compared to females. Indeed, the knowledge implicit in these systems does appear to be one source of the male advantage in mathematics-related tasks. Royer et al. (1999), meanwhile, propose that the reason for male superiority in mathematics is that they are faster than females in retrieving basic mathematical facts. According to those authors, boys' superiority over girls in math-fact retrieval surfaces in the fourth grade, continues through secondary education and is particularly significant in selected populations from the high end of the distribution curve. However, this supposedly more efficient retrieval function in boys in the performance of arithmetical problems was not seen by Imbo and Vandierendonck (2007). Another researcher, Spelke (2005), has suggested that any difference that may exist in mathematical performance between males and females is attributable to differences in strategy choices and not to differences between the genders in biologically predisposed aptitudes.

Learning strategies and cultural variables also potentially affect gender differences in arithmetical abilities (Butterworth, 2005; Campbell & Xue, 2001). It is noteworthy that the age trend seen in these gender differences in mathematics presents variations by countries (Mullis et al., 2003). In Mullis et al.'s international study, American boys showed a significantly higher overall score in mathematics than American girls at both grade levels (4 and 8). In the Philippines, in contrast, the same type of tests gave an advantage to girls over boys in the fourth and eighth grades, while in Japan no gender differences were observed.

The second question posed in this study is whether verbal and nonverbal cognitive nonmathematical tests would be predictive of gender differences in mathematical test performance. We hypothesized that the effects of gender on math outcomes are significantly reduced when verbal fluency and spatial nonverbal ability tasks are included. For purposes of this study, we defined spatial ability as the visual manipulation of images with a minimum of verbal mediation (Petersen, 1976). This prediction was based on two sets of evidence: (a) some authors have proposed that certain cognitive abilities that are nonspecific to number processing are also important in acquiring arithmetical skills. These other cognitive abilities include working memory (e.g., Ardila & Rosselli, 2002; Ashcraft, Donley, Halas, & Vakali, 1992; Bull & Scerif, 2001; Hope & Sherrill, 1987; Hulme & Mackenzie, 1992), spatial cognition (e.g., Dehaene, Piazza, Pinel, & Cohen, 2003; Rourke, 1993), and linguistic abilities (e.g., Bloom, 1994; Dehaene et al., 2003). (b) Males and females have shown somewhat different profiles in nonmathematical cognitive tests, with the strongest gender difference being reported for verbal and spatial abilities. Females outperform males in verbal tests such as verbal fluency (Burton, Henninger, & Hafetz, 2005; Loonstra, Tarlow, & Sellers, 2001) and, in particular, letter fluency (Strauss, Sherman, & Spreen, 2006). Males, on the other hand, tend to excel in nonverbal spatial tasks, such as spatial perception (Basso & Lowery, 2004; Linn & Petersen, 1985), mental rotation (Geary & De Soto, 2001; Voyer, Voyer, & Bryden, 1995), and spatial transformation tasks (Levin et al., 1999). It may be that such variations in performance between verbal and nonverbal neuropsychological tests help explain the gender differences that appear in math tests. It should be noted, however, that while research on gender differences in spatial skills performance seems to be consistent (Hyde, 2005; Voyer et al., 1995), reports on gender differences in verbal tasks have at times been contradictory (Mitrushina, Boone, Razani, & D'Elia, 2005; Roberts & Bell, 2002; Strauss et al., 2006).

METHOD

Participants

Two hundred and seventy-eight 7- to 10-year old children and 248 13- to 16-year-old children from private and public schools in Colombia and Mexico were selected. The first age group included children from the first to fifth grades and the second children from grades 7 to 11. Participants were recruited as part of a study on the normalization or standardization of a neuropsychological test battery called the *Evaluación Neuropsicológica Infantil* (*ENI*, "Child Neuropsychological Assessment"; Matute, Rosselli, Ardila, & Ostrosky-Solis, 2007). The *ENI* is a clinical neuropsychological test battery designed to assess a wide range of cognitive abilities in children between the ages of 5 and 16, which was developed, standardized, and normalized in Mexico and Colombia using a sample of 789 children. This test battery is now widely used in several Latin American countries.

Children were selected randomly from various classrooms using the lists of boys and girls provided by teachers. The parents of the children selected were then contacted and interviewed. Children with no history of failing grades and no parental reports of a history of neurological or psychiatric disorders were chosen. The sample included 231 boys and 295 girls: 488 right-handed, 27 left-handed and 1 with mixed-hand laterality. Gender distribution by age groups is presented in Table 1. The mean educational level of the children's parents was 12.43 years ($SD = 3.5$). No significant differences in the parents' level of education were observed between the two age groups, $F(1, 525) = 0.00$, $p = .95$, or between genders, $F(1, 525) = 0.10$, $p = .74$. All children voluntarily agreed to participate after obtaining permission from their parents or legal guardians and all were assessed individually at their schools. Each child received a small gift (e.g., a box of crayons, candy) after participating. Though no formal testing was done to rule out mental retardation or learning disabilities, we screened for grade retention to ascertain that no chronological-age/grade-level disparity was present and that school records showed that their performance in reading and math to be consistent with their chronological-grade levels.

Measures

Two types of cognitive measures were taken from the aforementioned Spanish-language neuropsychological test battery (*ENI*; Matute et al., 2007): (a) Six mathematical subtests and (b) two nonmathematical subtests. One of the latter subtests was verbal (verbal fluency) while the other was spatial and nonverbal (object integration). These two tests were selected based on previous evidence that revealed significant gender differences on these types of tasks (Basso & Lowery, 2004; Burton, Henninger, & Hafetz, 2005; Geary &

Table 1 General Characteristics of the Sample.

	7–10 yrs				13–16 yrs			
	Boys		Girls		Boys		Girls	
	N = 122		*N* = 156		*N* = 109		*N* = 139	
Characteristic	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Mean age in months	109.5	13.4	108.7	14.5	177.5	14.1	177.1	13.7
Parents' years of schooling	12.3	3.5	12.5	3.5	12.6	3.1	12.2	3.4

De Soto, 2001; Levin et al., 1999; Linn & Petersen, 1985; Loonstra et al., 2001; Strauss, Sherman, & Spreen, 2006; Voyer et al., 1995). Evidence for this is described above.

A. *Mathematical subtests*

1. **Reading Arabic Numbers.** The child is asked to read eight Arabic numbers written on a card (2, 6, 18, 263, 5,003, 70,049, 930,116, 402,005). The stability coefficient is .79 (Matute et al., 2007).
2. **Writing Arabic Numbers.** The child is asked to write the following series of dictated numbers: 1, 7, 61, 235, 8037, 42,001, 100,013, 6,050,010. The stability coefficient is .84 (Matute et al., 2007).
3. **Ordering of Numbers.** Eight numbers (123, 64, 89, 23, 110, 55, 46, 101) are shown to the child, who is then asked to order them from the smallest to the largest. The stability coefficient is .66 (Matute et al., 2007).
4. **Magnitude comparisons: (Number comparisons).** Two cards, each containing eight numbers (e.g., 301–310), are presented one-by-one. The child is asked to say the larger number on each card first, followed by the smaller one. The stability coefficient is .57 (Matute et al., 2007).
5. **Mental Math.** This subtest is called "mental" because the child has to do the calculations in "his/her head," without paper and pencil. This subtest included 12 individual arithmetical operations presented to the child orally: addition (2 + 3, 3 + 7, 23 + 14), subtraction (5 – 2, 11 – 7, 25 – 12), multiplication (5 × 3, 7 × 9), division (20 ÷ 2, 42 ÷ 7), and fraction problems (3/4 + 2/4, 1 – 2/3). The stability coefficient is .86 (Matute et al., 2007).
6. **Arithmetical Problems.** Eight worded arithmetical problems were included (deductive mathematical reasoning that includes two numerical propositions and asks the subject to provide a specific conclusion that follows logically from the two propositions). The examiner presented the child with a written version of each problem as it was read and this was kept in front of him/her until the problem was solved. The problems were in a story format that ranged from very easy (e.g., "If you have 3 apples and give 2 away, how many apples do you have left?"), to more difficult (e.g. "A second-hand motorcycle was sold for $8,700, which is ¾ of its original price. What was its original price?"). One point was given for each correct answer. The stability coefficient for this subtest is .79 and the correlation between the scores attained here and those of the Arithmetical Problems subtest from the Wechsler Intelligence Scale for Children-Revised (WISC-R) is .54 (Matute et al., 2007).

Rosselli, Matute, Ardila, and Pinto (2006) used mental math and arithmetical problems from the *ENI* and the Wide Range Achievement Test (WRAT-3; Wilkinson, 1993) with a sample group of children with dyscalculia and a control sample. To obtain external validity, we correlated the *ENI* Mental Math and Arithmetical Problems scores with those from the WRAT-3 obtained with that sample. Significant coefficients of .75 and .48, respectively, were found.

B. *Nonmathematical subtests*

1. **Verbal Fluency.** This test was used to evaluate spontaneous word production under a time restriction. The child was required to retrieve words that begin with the letter "M" within a time limit of 60 seconds. Letter fluency tests are believed to assess verbal initiative (Lezak, Howieson, & Loring, 2004; Mitrushina et al., 2005;

Strauss et al., 2006). Moreover, successful performance on fluency tasks requires certain executive functions, such as monitoring words and eliminating those that do not conform to the rules of the task (Anderson, Levin, & Jacobs, 2002). Performance on Verbal Fluency tests has been shown to contain a substantial verbal component (Strauss et al., 2006) and stronger correlations with Verbal IQ than with Performance IQ (Anderson, Anderson, Northman, Jacobs, & Catroppa, 2001). The score on this test was recorded as the total number of correct words. The stability coefficient is .76 (Matute et al., 2007).

2. **Object Integration.** This test was used to assess visual spatial perceptual organization (Matute et al., 2007). The test consists of eight cards, each one with a target object and four fragments of that object. The child must decide which of the four options completes the target object. In order to obtain the correct answer, he/she must imagine how the fragmented parts fit together. The score reflects the number of correct choices. The child is not required to name the object. The stability coefficient for this subtest is .68 (Matute et al., 2007). Similar stability coefficients have been reported for visuospatial tests, such as the NEPSY Arrows subtest (Korkman, Kirk, & Kemp, 1998). To analyze external validity for the Object Integration subtest, we calculated the correlations of this measure with other subtests used in the original standardization of the *ENI* (Matute et al., 2007) and found significant correlations with the WISC-R Object Assembly (.58) and Block Design tests (.41), but a nonsignificant correlation with the WISC-R Vocabulary test (.29). The significant correlation with the first two subtests and the lack of significance with the latter one support the nonverbal spatial component of this test.

Statistical Analyses

Two different types of analyses were conducted. First, ANOVAs were performed to examine the main effects and interactions of age and gender for each mathematical and nonmathematical subtest. The effect sizes were assessed using partial eta^2 ($p\eta^2$) for overall group differences. Type I error probability was set to .05.

The second analysis aimed to pinpoint the cognitive nonmathematical correlates of arithmetical skills for boys and girls after controlling for age. Hierarchical multiple linear regression analyses were conducted using the mathematical subtests as dependent variables and gender and the verbal and nonverbal cognitive tests as the independent variables. The latter were entered in three steps: the age factor in the first step, followed by the introduction of gender in the second. In the third, each nonmathematical cognitive measure was entered as a predictor, in parallel steps, in order to examine the contribution of these variables over and above the effects of age and gender, with gender coded as a between-group factor (dummy variable; 1 = female and 0 = male).

Since the aim of the regression analyses was to identify mediators of gender differences in math tasks, we used only those mathematical tests in which gender differences were statistically significant.

RESULTS

Table 2 presents the means, standard deviations, and age and gender effects for each mathematical subtest. In general, standard deviations were lower in the older group compared to the younger one, suggesting more heterogeneity in younger participants.

Univariate *F*s showed that the age-group effect was significant for all mathematical measures, as scores improved with age. Gender had a significant effect on two measures: Mental Math and Arithmetical Problems, where boys scored significantly higher than girls. This effect was independent of the age-group effect for Mental Math, but a significant Age × Gender interaction was observed for Arithmetical Problems. There, boys' scores were significantly higher than girls', $F(1, 247) = 21.63$, $p = .0001$ (see Figure 1).

Multiple regressions were conducted to determine the best linear combination of age, gender, and the Verbal Fluency and Object Integration tests for predicting performance on mathematical tests. Only Arithmetical Problems and Mental Math were included as

Table 2 Means (Standard Deviations) and Main Effects of Age and gender on the Math Subtests.

	Age Groups							
	7–10 yrs		13–16 yrs		Age effect		Gender	
Test	Boys	Girls	Boys	Girls	*F*	(η^2)	*F*	(η^2)
Reading Numbers	5.8 (2.6)	6.2 (2.3)	7.6 (.88)	7.5 (1.3)	137.3**	.25	0.04	.00
Writing Numbers	5.7 (1.7)	5.4 (1.7)	7.4 (.71)	7.2 (1.1)	155.46**	.27	2.90	.01
Magnitude Judgments	5.7 (2.8)	4.8 (2.6)	7.7 (.52)	7.6 (1.0)	90.7**	.18	.56	.00
Ordering Numbers	7.2 (2.0)	7.2 (2.1)	7.9 (.1)	8.0 (.00)	34.9**	.06	.02	.00
Mental Math	7.4 (2.8)	7.1 (3.1)	10.8 (1.5)	10.1 (1.5)	189.5**	.32	4.70*	.01
Arithmetical Problems +	3.9 (1.5)	3.8 (1.6)	5.8 (.95)	5.2 (1.1)	206.16**	.28	9.98**	.02

*$p < .01$ **$p < .001$; $p\eta^2$ = *partial eta square.* + Interaction ($F = 7.03$, $p = .008$, $\eta^2 = 0.02$).

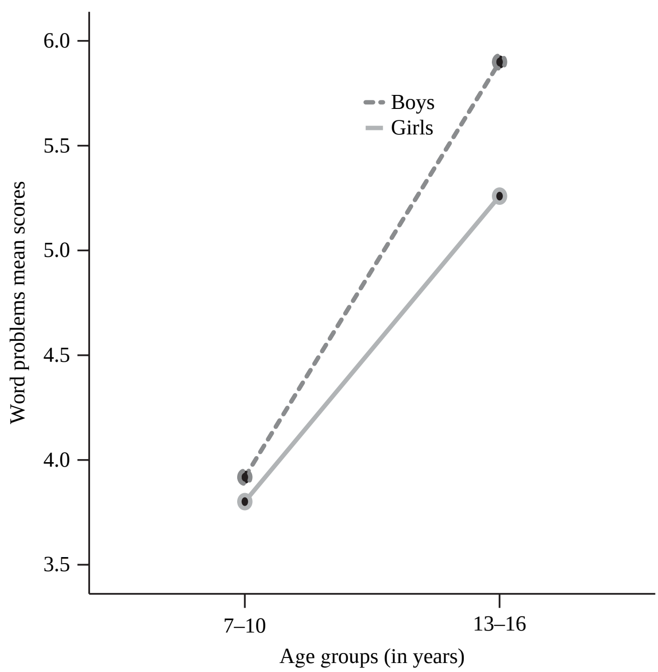

Figure 1 Significant age × gender interaction in arithmetical problems.

Table 3 Boys' and Girls' Performance on Nonmathematical Tasks, Means, Standard deviation (in parenthesis) Univariate *F* for Age and Gender Effects, and Partial Correlations are Presented.

	7–10 yrs		13–16 yrs		Age effect		Gender effect		Partial Correlations	
Test	Boys	Girls	Boys	Girls	*F*	$p\eta^2$	*F*	$p\eta^2$	MM	AP
Verbal Fluency	6.9 (3.0)	7.2 (3.2)	12.2 (3.8)	13.3 (3.8)	339.84**	.40	3.84*	.05	.27**	.23**
Object Integration	3.8 (1.6)	3.8 (1.4)	5.4 (1.6)	4.6 (1.6)	56.97**	.12	5.88*+	.01	.35**	.32**

*$p < .05$; **$p < .01$; $p\eta^2$ = partial *eta* square; + Interaction is significant $F = 6.90$**, $p\eta^2 = .02$; MM = Mental Math; AP = Arithmetical Problems.

dependent measures, as they were the only ones that revealed gender differences. Table 3 presents the means and standard deviations for boys and girls from the two age groups for each nonmathematical (Verbal Fluency and Object Integration) predictor and its partial correlations, after controlling the Arithmetical Problems and Mental Math results for age. Age and gender proved to have a significant effect on both measures, with boys performing better than girls in Object Integration $F(1, 522) = 6.25$, $p < .01$, but girls scoring significantly higher than boys in Verbal Fluency, $F(1, 522) = 3.84$, $p < .05$. A significant interaction was found for Object Integration, where only boys in the older group performed better than girls. No significant interaction was found for Verbal Fluency.

Table 4 presents a summary of the multiple regression analyses using Verbal Fluency and Object Integration as predictors of Arithmetical Problems and Mental Math. The adjusted R^2s indicate that age is the most important predictor of the dependent math measures, as it accounts for 29% to 30% of the variance. When gender is entered into the model together with age it significantly predicts an additional 1% of the variance in Mental Math scores and an additional 2% of the variance in Arithmetical Problem scores. The adjusted R^2 change was significant for both dependent measures: $F(1, 523) = 447$, $p = .03$ and $F(1, 523) = 8.39$, $p = .004$, respectively. Another 5% of the variance in Mental Math and 2% of the variance in Arithmetical Problems is explained by the combination of gender and the verbal fluency task, as indicated by the changes in R^2 (step 3A), $F(1, 522) = 447$, $p = .03$ and $F(1, 522) = 8.39$, $p = .004$, respectively. An additional 8% of the variance in Mental Math and Math Problems is explained by grouping together gender and the Integration of Objects subtest (step 3B), as reflected in the significant changes in R^2 for Mental Math, $F(1, 522) = 50.38$, $p < .0001$, and Arithmetical Problems $F(1, 522) = 50.98$, $p < .001$. The beta weights for Verbal Fluency and Object Integration showed that the effects of gender on Mental Math declined significantly when Object Integration — but no Verbal Fluency — was entered into the model. The beta weights presented in Table 4 demonstrate that both Verbal Fluency and Object Integration scores are significant individual predictors of performance in the two math subtests.

DISCUSSION

Results showed that boys and girls in both age groups scored very similarly in most mathematical subtests and that the only gender differences emerged in the Mental Math and Arithmetical Problem subtests. The performance of boys and girls in Reading and

Table 4 Hierarchical Multiple Regression Analysis for Nonmathematical Tests Predicting Arithmetical Problems and Mental Math.

Model	Predictor	Adjusted R^2	*B*	*SEB*	β
Dependent measure: Mental Math					
1	Age		3.24	.23	.56**
		.31*			
2	Age		3.23	.23	.55**
	Gender		−.50	.23	−.09*
		.32*			
3A	Age		2.05	.30	.36**
	Gender		−.63	.22	−.10**
	Verbal fluency		.19	.03	.31**
		.37**			
3B	Age		2.66	.24	.46**
	Gender		−.13	.22	−.05
	Object Integration		.49	.07	.29**
		.40**			
Dependent measure: Arithmetical Problems					
1	Age		1.69	.12	.52**
		.29**			
2	Age		1.69	.11	.52**
	Gender		−.34	.12	−.11**
		.31**			
3A	Age		1.15	.14	.36**
	Gender		−.40	.11	−.12**
	Verbal fluency		.09	.01	.27**
		.33**			
3B	Age		1.52	.11	.47**
	Gender		−.26	.11	−.08*
	Object Integrations		.28	.04	.29**
		.39**			

$p < .05$; $**p < .01$.

Note. 3A and 3B were parallel steps.

Writing Numbers, Magnitude Judgments, and Ordering Numbers was virtually identical. However, a gender effect was observed when the tasks involved mental arithmetic and solving arithmetical problems, with boys scoring significantly higher than girls. Also, a significant interaction between age and gender was observed for Arithmetical Problems, where older boys performed at a significantly higher level than older girls. It is important to note that similar to previous findings (Hyde, 2005) this study found that the magnitude of the effect sizes associated with significant gender differences in math was very small.

The absence of a gender effect on the subtests involving number knowledge (such as reading and writing numbers) was expected, as previous research has shown that these abilities that some consider primary numerical skills, show no gender differences and are less affected by cultural factors than secondary numerical abilities (e.g., Dehaene, 1997; Nunes & Bryant, 1996). Primary numerical skills include understanding numerosity (e.g., determining the quantity of small sets of items by estimation), ordinality (e.g., understanding the notions “more than” and “less than”), counting (e.g., enumeration of small sets), and simple arithmetic (Butterworth, 1999). Secondary numerical skills, on the other hand, include computations and are built upon the primary skills according to an individual's culture and educational experience (Geary, 1996, 2000). For example, greater concentration on mathematical instruction and attitudes toward mathematical achievement has been used to explain the advantage in computation among Asian children compared to North American children (Chen & Stevenson, 1995).

Most individual variability in mathematical skills in terms of culture and gender has been reported for computation skills (Geary, Bow-Thomas, Liu, & Siegler, 1996). In this study, older boys outperformed older girls when solving individual oral arithmetical operations and problems. Several strategies have been described in relation to children's performance on these types of problems, including direct memory retrieval (knowing that 5 + 3 = 8), decomposition (6 + 8 = 6 + 6 + 2) and counting (4 + 4 = 4, 5, 6, 7, 8) (Geary & Brown, 1991; Geary, Brown, & Samaranayake, 1991). The use of these strategies is affected by both age and gender. For example, Imbo and Vandeirendonck (2007) found that fifth and six graders tend to use retrieval more often and more efficiently than fourth graders and, in addition, that boys use memory retrieval more frequently than girls. The latter results in better performance in math tasks and it may be reasonable to suggest that the higher performance of boys in the calculation tests used in this study could be associated with a more efficient retrieval technique. Also interesting is the fact that differences in patterns of neural activation between males and females during calculation tasks have been reported (Kucian, Loenneker, Dietrich, Martin, & Von Aster, 2005).

Our results indicating higher scores for boys than girls in solving Arithmetical Problems support previous findings (Hyde et al., 1990). The higher performance of boys compared to girls in computation, however, contradicts Hyde et al.'s results, as they found a female superiority in tasks that require "the use of only algorithmic procedures to find a single numerical answer" (p. 141). Our results showed no significant superiority for girls' scores in any of the mathematical subtests. Differences between the characteristics of the sample groups in these two studies may explain this disparity in results: whereas Hyde et al.'s samples came from the United States and Canada, our sample was selected from Mexico and Colombia. Variations in results related to gender differences in mathematical skills across different countries have been reported previously (Mullis et al., 2000, 2003).

The predicted significant interaction between gender and age was found for Arithmetical Problems. Boys' performance was better than girls', but only in the older group. The developmental trend in our results partially matches the findings reported by Hyde et al. (1990), who also found that the male advantage in problem solving was not present in elementary or middle school but emerged in high school. However, unlike our study, Hyde et al. found a small gender difference in computation that favored girls in elementary school and middle school, but no gender difference in high school.

Arithmetical problems, also called arithmetic word problems, are thought to represent a link between the child's developing computational abilities and his/her capacity to apply these skills to real life (Geary, 1994). Our results showed that learning to solve arithmetical problems improves with age. This learning requires not only the fast retrieval of facts but also the application of arithmetic concepts and principles. In kindergarten and first grade, most children are able to solve problems that involve some type of action performed by the child him/herself (i.e., John has two cars and Bill gave him two more, how many cars does Juan have?) and problems that combine subsets to obtain the correct answer (i.e., John has three cars and Bill has two, how many cars do they have together?) (Geary, 1994). First graders have difficulties in solving problems that require greater than/ less than comparisons. Performance on this type of problem improves by the second and third grades (Riley & Greeno, 1988). Between the third and fifth grades, children develop abilities to solve “equalize” problems (Geary, 1994). In this type of problem the child performs an arithmetic operation that results in a change in the quantity of one of the sets involved (i.e., John has two cars. Bill has 6 cars. How many cars does John have to buy to have as many as Bill?).

Cognitive development, such as the ability to solve problems, seems to improve sequentially through childhood, and this improvement appears to coincide with increased myelination, the developmental regression of redundant connections and growth spurts during the maturation of the cerebral cortex (Anderson et al., 2001). For example, the development of working memory capacity in children has been correlated with increased cortical activity in the frontal and parietal lobes (Klinberg, Forssberg, & Westerber, 2002; Kwon, Reiss, & Menon, 2002) and with greater maturation of white matter (myelination and axonal thickness), especially in the left frontal lobe (Nagy, Westerberg, & Klingberg, 2004). Though a consensus exists that brain development during childhood and adolescence is characterized by a reduction of gray matter and an increase in the volume of white matter (Hua et al., 2007; Sowell et al., 1999, 2004), gender effects have also been suggested. For instance, De Bellis et al. (2001) found a greater age-related decline in gray matter and corresponding increase in white matter in boys as compared to girls. Although, girls also showed significant developmental changes, these modifications took place at a slower rate than in boys. These gender differences in brain development have been corroborated by other authors (Wilke, Krägeloh-Mann, & Holland, 2007). Thus, it seems plausible to suggest that the significant age-by-sex interaction found for Arithmetical Problems in our study is associated with the sex-by-age interaction that has been shown with respect to sex differences in brain volumes. Future research should corroborate this assumption.

After controlling for age, gender alone explained a small but significant proportion of the variance on Arithmetical Problems and Mental Math. Consistent with our hypothesis, the spatial predictor mediated the gender effects on Mental Math. When Object Integration was entered into the regression equation there was a significant reduction of gender effects, a result that suggests that scores on this spatial test serve as a significant mediator of gender differences in Mental Math. Object Integration, while a significant predictor of Arithmetical Problems, did not mediate gender effects.

Our results, as well as previous research, provide evidence for the involvement of spatial cognition in numerical abilities (e.g., Fias & Fischer, 2005). This study corroborates the importance of spatial abilities as the explanation of gender differences in certain calculation skills, such as doing calculations in one’s head. It is interesting that the predictive value of spatial skills for the better mathematical performance of males has been found by some authors (Casey, Pezaris, & Nuttall, 1992) but not by others (Friedman, 1995). Hence, the association between visuospatial skills and gender differences in math remains controversial and seems to be significantly influenced by the type of math task involved.

The results from the present study show that when verbal fluency is entered into the model an additional proportion of the variance on the two mathematical subtests was explained, indicating the contribution of verbal skills to performance on arithmetical tasks. This finding emphasizes that mathematical abilities are affected not only by visuospatial skills (e.g., Fias & Fischer, 2005) but also by verbal abilities (Ardila & Rosselli, 2002).

Scores on the Verbal Fluency task used in this study did not mediate gender effects on either Mental Math or Arithmetical Problems. In other words, whereas high scores on verbal fluency tasks seem to be associated with high scores in math performance, this relationship does not help to explain gender differences on math tests. These findings make it clear that nonverbal spatial tests are more important in explaining the differences in math scores between boys and girls. However, it should be noted that verbal fluency tasks such as the one used here have an important executive function component and require working memory resources (Anderson et al., 2001), whereas tasks such as the visuospatial one used do not meet this condition. Future research should explore the contribution of verbal tasks to understanding math abilities in boys and girls in the absence of working memory conditions.

This study has several limitations, one of which was that the number of items included in each subtest was small. In the mental subtests, a mix of addition, subtraction, and multiplication operations was included in the same subtest; additionally, one- and two-digit arithmetical operations were included in Mental Math, and this did not permit a specific error analysis per arithmetical domain. Moreover, some of the items included in certain calculation subtests were very difficult for the younger group and thus presented a potential flooring effect; while they proved quite easy for the older group and therefore may have resulted in a ceiling effect. This type of problem is understandable when a test is designed for a large age range. However, the fact that age had a significant effect on all measures demonstrates the developmental validity of the instrument. In addition, it is important to consider that the age range in each group was relatively broad; consequently we cannot assume from this study that the cognitive requirements involved in each task were the same within each group. Lastly, this study uses age samples in a cross-sectional design that does not preclude the potential effects of cohort variables such as educational differences, changes in curriculum, etc.

In conclusion, this study supports the interaction of age and gender in the performance of some arithmetical tasks among school-age children, with boys outperforming girls in the older group only. The gender effect found in this study is small in magnitude and is not present in tasks that involve numerical knowledge. Larger magnitude gender effects for more complex mathematical problems have been found in 15- to 18-year-olds (Hyde et al., 1990). Future longitudinal research with samples older than the ones included in the current study is required to corroborate the developmental trend of our findings. Fluctuations in the magnitude of gender differences at different ages have been reported for complex mathematical skills (Hyde, Fennema, & Lamon, 1990), so it is expected that upon including a larger age range, the developmental trend of gender differences would be more evident.

Another conclusion from our study is that both verbal and nonverbal nonmathematical tasks predicted performance on mathematical tests, but only the visuospatial task was a mediator of gender differences in math test scores. This conclusion is limited by the fact that we only used one verbal and one nonverbal test. Future research using a spectrum of verbal and spatial skill tests should corroborate these findings.

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