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Development of early numerical abilities of Spanish-speaking Mexican preschoolers: A new assessment tool

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ABSTRACT

This article presents a tool for assessing the early numerical abilities of Spanish-speaking Mexican preschoolers. The Numerical Abilities Test, from the *Evaluación Neuropsicológica Infantil-Preescolar* (ENI-P), evaluates four core abilities of number development: magnitude comparison, counting, subitizing, and basic calculation. We evaluated 307 Spanish-speaking Mexican children aged 2 years 6 months to 4 years 11 months. Appropriate internal consistency and test–retest reliability were demonstrated. We also investigated the effect of age, children's school attendance, maternal education, and sex on children's numerical scores. The results showed that the four subtests captured development across ages. Critically, maternal education had an impact on children's performance in three out of the four subtests, but there was no effect associated with children's school attendance or sex. These results suggest that the Numerical Abilities Test is a reliable instrument for Spanish-speaking preschoolers. We discuss the implications of our outcomes for numerical development.

KEYWORDS
Assessment tool; early numerical abilities; preschoolers; psychometrics; SES

Infants show an understanding of numbers from birth (De Hevia, Izard, Coubart, Spelke, & Streri, 2014; Izard, Sann, Spelke, & Streri, 2009), and they start the protracted process of learning the meaning of number words and counting as early as two years of age (Wynn, 1990, 1992). Sometime later, they develop an understanding of quantifiers (e.g., "more") and start to perform basic arithmetic (Huttenlocher, Jordan, & Levine, 1994; Odic, Pietroski, Hunter, Lidz, & Halberda, 2012). However, not all children develop these abilities at the same pace: There are large individual differences that can affect their later academic performance (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006).

Several studies have reported the predictive value of early numerical abilities for later educational achievement (Duncan et al., 2007; Jordan & Levine, 2009; Romano, Babchishin, Pagani, & Kohen, 2010). In a meta-analysis, Duncan et al. examined the predictive power of scores obtained in early mathematical, prereading, and attention tasks, as well as socioemotional behaviors, measured in kindergarten. They found that in comparison with other measures, scores in early mathematical abilities tasks (e.g., counting up to ten and digit recognition) were the strongest predictors of academic achievement through elementary school. Although these results highlight the importance of reliable assessment tools for the evaluation of numerical abilities in early childhood, no such tools exist for Spanish-speaking Mexican preschoolers. This article presents the new Numerical Abilities Test, part of the forthcoming *Evaluación Neuropsicológica Infantil-Preescolar* (ENI-P; Matute, Rosselli, & Beltrán-Navarro, in press), as one such tool for these children.

Development of numerical abilities in early childhood

Research has identified two broad categories for early numerical abilities: nonsymbolic numerical abilities, those that can be performed without symbols, such as comparing the number of objects of two collections or performing approximate arithmetic(Gilmore, McCarthy, & Spelke, 2010); and symbolic numerical abilities, those in which symbols (e.g., number words and digits) are involved (Carey, 2009).

Nonsymbolic numerical abilities begin to develop from birth. Studies have found that newborn infants are capable of associating a sequence of syllables with a collection of objects that have the same numerosity

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(Coubart, Izard, Spelke, Marie, & Streri, 2014; Izard et al., 2009). According to some authors (Feigenson, Dehaene, & Spelke, 2004; Le Corre & Carey, 2007; Piazza, 2010), the underlying cognitive system for these abilities is the Approximate Number System (ANS). Typically, performance in number comparison tasks (i.e., determining which of two collections of dots has the larger numerosity) has been taken as a measure of ANS precision (Halberda, Mazzocco, & Feigenson, 2008). Stable individual differences in ANS precision have been reported from the age of six months (Libertus & Brannon, 2010). More importantly, these individual differences in infancy can predict symbolic numerical knowledge (e.g., counting and basic calculation skills) at the age of 3.5 years (Starr, Libertus, & Brannon, 2013). It has also been reported that children's performance in a number comparison task at age three predicts their scores in a mathematical standardized assessment at age six (Mazzocco, Feigenson, & Halberda, 2011), and that preschoolers' performance in such tasks correlates with their understanding of counting, specifically their understanding of the cardinality principle (Abreu-Mendoza, Soto-Alba, & Arias-Trejo, 2013).

The second cognitive system for number representation is the Object Tracking System (OTS), which allows tracking of up to four objects (Feigenson & Carey, 2003). This system underlies the ability to subitize, that is, to make an accurate, rapid assessment of the number of objects in a collection of up to four objects (L. Kaufman, Lord, Reese, & Volkmann, 1949; Piazza, 2010). Prior to learning to count, children employ this ability to enumerate small collections (1–3 objects; Starkey & Cooper, 1995). Children with developmental dyscalculia show lower performance levels in subitizing tasks, highlighting their importance for the development of numerical abilities (Schleifer & Landerl, 2011). Together, the OTS and the ANS allow humans and nonhuman animals to represent numerical quantities.

Number comparison abilities are closely related to the ability to compare non-numerical quantities such as area, size, and duration (Cordes & Brannon, 2008). Six-month-olds, for example, show similar precision in discriminating changes in number, duration, and area (Brannon, Lutz, & Cordes, 2006; Brannon, Suanda, & Libertus, 2007). These abilities also contribute to mathematical development. Two recent studies have found that four-to-seven-year-olds' ability to compare cumulative area (Lourenco & Bonny, 2016) and the area of 2-D figures (Bonny & Lourenco, 2015) correlates with measurements of their mathematical competence and their understanding of geometric concepts. These findings are consistent with an earlier report of a relationship between scores in an area comparison task and standardized scores in a geometric knowledge subtest in adults (Lourenco, Bonny, Fernandez, & Rao, 2012).

One milestone of numerical development that occurs in childhood is learning to count (Butterworth, 2010; Carey, 2009). Children around the age of two and a half years begin the protracted process of mapping non-symbolic numerical representations to symbols (e.g., number words). According to Gelman and Gallistel (1978), learning to count is guided by what they term the three How-to-Count principles: the one-to-one correspondence principle, the stable order principle, and the cardinality principle. Each of these principles is acquired at a different age. Typically developing children show understanding of the one-to-one correspondence principle at the age of 18 months (Slaughter, Itakura, Kutsuki, & Siegal, 2011). Around 2 years of age, they start to recite number words in a stable order, before understanding their meaning. Finally, a year and a half later, they understand that the last word produced in counting equals the total number of objects in the collection that is counted (i.e., the cardinality principle; Wynn, 1990, 1992). There is a large variability in children's knowledge of counting (Negen & Sarnecka, 2012; Sarnecka & Lee, 2009); although it has been reported that children use the cardinality principle around the age of 42 months, have shown that some children use this principle as early as 35 months and others as late as 50 months.

Understanding individual differences: The role of sex and socioeconomic status

Children's sex and parents' socioeconomic status (SES) explain some of the variance found in children's mathematical scores (Anders et al., 2012; Jordan et al., 2006; Jordan & Levine, 2009; Siegler, 2009; Wang et al., 2015). Although the results have not been consistent, some studies have reported sex differences regarding mathematical and numerical competence. Jordan et al. (2006) found that five-year-old boys outperformed girls of the same age in a number sense, nonverbal calculation, and estimation task; girls had an overall score of 37.21, while boys scored 2.77 points higher. However, in a study considering performance in the number sense assessment as a predictor variable for children's performance in the Calculation and Applied Problems Subtests of the Woodcock-Johnson III test (WJMath; Woodcock, McGrew, & Mather, 2001), sex did not add explanatory variance in first-grade children (Jordan et al., 2007). These studies suggest that the influence of sex over mathematical abilities in childhood is complex and requires further analysis.

The influence of SES on children's numerical abilities has been consistently shown. Differences between the performance of low-income children and middle-income children in counting, finding numerical relationships, and basic arithmetic has been found as early as entry to kindergarten (Jordan et al., 2007; Jordan et al., 2006). Furthermore, children from low-income backgrounds are at greater risk of developing a learning disability: The percentage of children and adolescents aged three to 17 years from low-income families who have difficulties in learning to read, write, or do arithmetic is higher than the percentage of children from middle-incomes homes (8.3% vs. 6.1%; Brooks-Gunn & Duncan, 1997).

Another factor related to SES but with a possible independent effect is preschool quality. Recently, Anders et al. (2012) found a relationship in preschool children between initial numeracy skills and class size, average age in a class, child-staff ratio, and space per child. It has also been reported that preschool programs serving middle-income children result in more gains in mathematical abilities than those serving low-income children (Clements & Sarama, 2008).

Assessment of numerical abilities in preschool age children

In contrast to the large number of assessment tools for evaluating children's speech and language (see McCauley & Swisher, 1984; McLeod & Verdon, 2014), there are only a few tests that evaluate early numerical abilities. For an overview of these tests and their subtests, we searched for those available in either English or Spanish in the catalogs of two of the major publishers of assessment instruments in the United States (Pearson Education and Psychological Assessment Resources), one of the major publishers in Spain (TEA Ediciones), and one of the major publishers in Mexico (Manual Moderno), using the following criteria: (a) a specific index for numerical abilities; (b) availability online of the test manual or a description of its psychometric properties; (c) norms available for children up to 4 years of age; and (d) publication or last update within the previous 15 years. The six instruments meeting these criteria, of the nine that evaluate children's numerical abilities as young as 4 years of age, are shown in Table 1. Two instruments—the Bayley Scales of Infant and Toddler Development-III (Bayley, 2006) and Boehm-3 Preschool (Boehm, 2001)—were excluded because, although they have some items that evaluate numerical abilities, they do not have specific indices. The Kaufman Survey of Early Academic and Language Skills (A. Kaufman, 1993) was excluded because it was published more than 15 years ago.

Among these six instruments, the youngest age evaluated is 3 years and almost all of them evaluate counting. Critically, there is no instrument for Spanish-speaking Mexican children. Although there are instruments in Spanish, they may not be appropriate for Mexican children owing to cultural and dialectal differences between Mexico and Spain.

The current study

Inspired by the developmental literature, we designed a new instrument, the Numerical Abilities Test, as part of the *Evaluación Neuropsicológica Infantil-Preescolar* (ENI-P; Matute et al., in press), and analyzed its internal consistency and test-retest reliability in Spanish-speaking Mexican children aged 2 years 6 months to 4 years 11 months. To compare children's performance across different ages, we selected only tasks that were appropriate within this age range (Jordan & Levine, 2009): a basic calculation task, a magnitude comparison task, a counting task, and a subitizing task. To explore whether the instrument captured the developmental changes occurring in this age range, we divided children into five age groups. To assess the effects of SES on children's performance, we employed mothers' years of education as an index of SES and divided children into two groups: those with mothers below the Mexican national mean educational level for women (<9 years) and those with mothers equal or above the mean (Instituto Nacional de Estadística y Geografía, 2015). Finally, we assessed the effect of sex and school attendance on children's numerical scores.

Methods

Pilot studies

Before evaluating the final sample, we performed two pilot studies to determine the appropriateness of the subtests (see Figure 1). Children from both pilot studies were in public or private daycare or not in daycare. In Pilot 1, there were five children who did not attend preschool, three in public preschools, and twelve in private ones, while in Pilot 2 there were six in private preschools and two who attended no preschool. Parents of all children gave their written informed consent. In the first study, we estimated the internal consistency reliability of the Magnitude Comparison Subtest, Counting Subtest, and Basic Calculation Subtest; in the second, we estimated that of the Subitizing Subtest.

Table 1. Psychological assessment instruments for early numerical abilities.

Name of instrument	Country of publication (norms)	Language	Sample Size	Age range	Administration	Tasks	Psychometric properties
Bracken Basic Concept Scale - Third Edition: Receptive (Bracken, 2006)	USA	English/Spanish adaption**	750 & 61	3–6:11 years	Individual 30–35 minutes	Subtests: numbers/counting, sizes/comparison, and quantity	R = .78–.97 T/R = .86
Evaluación neuropsicológica infantil 2 (Matute, Rosselli, Ardila, & Ostrosky, 2014)	México	Spanish	788	5–16 years	Individual	Mathematical subtests (e.g., arithmetical problems, counting, magnitude comparsions, mental math)	T/R = .35–.86
Feifer Assessment of Mathematics (Feifer & Kovach Clark, 2016)	USA	English	1,061	4–21 years	Individual 35–50 minutes	Procedural index, verbal index, and semantic index	R = .71–.93
TEDI-MATH (Grégoire, Nöel, & Van Nieuwenhoven, 2015)	France & Spain	French/Spanish	583	4–8 years	Individual ~1 hour	Knowledge of the number-word sequence, counting sets of items, knowledge of the numerical system, and logical operations on numbers	R = .70–.97
Test of Early Mathematics Ability (Ginsburg & Baroody, 2003; Ginsburg, Baroody, del Río, & Guerra, 2007)	USA & Spain	English/Spanish	1,219	3–8:11 years	Individual 30–45 minutes	Numbering skills, number comparison facility, number literacy, mastery of number facts, calculation skills, and understanding of concepts	R = .92 T/R: .93
Wechsler Individual Achievement Test-III (Wechsler, 2009)	USA	English	2,775	4–50:11 years	Individual	Math problem solving, numerical operations, math fluency-addition, math fluency-subtraction, math fluency-multiplication	R = .83–.97
Woodcock & Johnson IV Tests of Early Cognitive and Academic Development (Schrank, McGrew, & Mather, 2015)	USA	English	2,378	2 ½–9:11 years	Individual	Subtest: number sense	R = .79

Note. R = reliability; T/R = test–retest.

The results showed good internal consistency for all subtests. Based on the floor performance of the 17-to-29-month-olds, we set the initial age for the main study at 30 months.

Current study

Participants

Three hundred and seven preschoolers (mean age = 3.69 years, $SD = 0.71$, 159 girls) participated in this study. Children and their families were recruited from four different states in Mexico. In order to capture developmental changes, five age groups spanning six months each were defined: 2;06–2;11 years ($n = 66$), 3;00–3;05 years ($n = 63$); 3;06–3;11 years ($n = 60$), 4;00–4;05 years ($n = 63$), and 4;06–4;11 years ($n = 55$). The following inclusion criteria were applied: (a) full-term births: $\geq$37 weeks of gestation; (b) birth weight: 2500–3999 grams (5.5–8.8 lbs.); and (c) no report of complications that could affect the development of the nervous system. No significant sociodemographic differences were found among age groups (see Table 2).

In Mexico, preschool attendance is not yet universal: only 70% of children attend. Most of these attend public preschools (85.8%; INEE, 2015). To reflect these characteristics of preschool attendance, we evaluated more children who attended public preschools ($n = 189$ [61.6%]) than private ones ($n = 89$ [29%]), in addition to a small percentage that did not attend any preschool ($n = 29$ [9.4%]).

Measures

Magnitude Comparison Subtest. Because studies have shown that children's mathematical abilities are related to the ability to compare continuous as well as numerical quantities (Lourenco & Bonny, 2016), we included trials in which children were asked to compare both object sizes and numerical quantities. In the continuous quantities trials, children were asked to point to the larger or smaller object; in the numerical quantities trials, they were asked to point to the group with the larger or the smaller number of objects. For each item, the experimenter showed children either a card with three objects (differing in size) or one with three sets of different quantities of objects. There was also one item in which children were asked to point to the two sets with the same number of objects. There was a total of seven items and a maximum possible score of seven.

Counting Subtest. This subtest evaluated children's knowledge of the How-to-Count principles (Gelman & Gallistel, 1978). Children were shown a card with ten cartoon drawings of chicks. The examiner asked each

Table 2. Comparison of sociodemographic characteristics of age groups.

Variables	N	Age group (years; months) 2;06–2;11	3;00–3;05	3;06–3;11	4;00–4;05	4;06–4;11	x^2	p
Categorical variables								
State							6.39	.89
Baja California	14	2	4	2	3	3		
Jalisco	192	41	38	39	37	37		
Michoacán	60	15	15	12	11	7		
San Luis Potosí	41	8	6	7	12	8		
Sex							0.52	.97
Female	159	33	31	33	33	29		
Male	148	33	32	27	30	26		
Family members in household							9.14	.69
Both parents	257	58	55	51	49	44		
Mother	46	8	7	8	12	11		
Mother and stepfather	3	0	1	1	1	0		
Maternal aunt	1	0	0	0	1	0		
Mother's employment							5.29	.25
Employed	229	52	51	39	45	42		
Unemployed	78	14	12	21	18	13		
Father's employment[a]							4.22	.37
Employed	254	58	53	51	48	44		
Unemployed	1	0	0	0	1	0		
Mother's education							5.78	.21
0–9 years	51	9	7	14	14	7		
10–25 years	256	57	56	46	49	48		
Father's education							5.04	.28
0–9 years	58	12	11	10	17	8		
10–25 years	197	46	42	41	32	36		

	Continuous variables M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p
Mother's age (years)	30.91 (5.25)	30.03 (6.00)	29.9 (5.04)	32.29 (6.19)	32.15 (5.77)	2.34	.055
Father's age (years)	33.25 (6.13)	32.61 (6.87)	33.30 (5.84)	34.58 (7.92)	35.87 (6.61)	1.89	.110

Note. [a]Father's employment and education are reported only for those who lived with the child.

child to count out loud and tell her how many chicks there were. Children were given one point if they pointed to each chick while reciting the count list (one-to-one correspondence principle), one point for each number word recited correctly (stable order principle), and one point if they said the correct number of objects (ten) out loud (cardinality principle). The maximum possible score was 12: ten points for correctly reciting the count list up to ten and two for following the one-to-one correspondence and cardinality principles.

Subitizing Subtest. This subtest resembled the one proposed by (Starkey & Cooper, 1995). The examiner began by telling children they were going to see some cards and that they should say out loud how many stars there were. Children saw collections of one to five stars in the following order: 3, 5, 1, 4, 2. One point was given for each correct response. There was a total of five items and a maximum possible score of five.

Basic Calculation Subtest. This subtest is similar to the story problems employed in other assessments tools (e.g., Jordan et al., 2006); however, in order to simplify the task for younger children, they were asked merely to point to the correct answer. The examiner presented two basic arithmetic problems, one of subtraction and another of addition. In the subtraction problem, children were shown a card with three images: In the upper center of the card there were three lollipops; in the lower left and lower right corners there were three and two lollipops, respectively. The examiner said (in Spanish): "Look, I had three lollipops and I ate one. How many are left? These (pointing to the lower left corner) or these (pointing to the lower right corner)?" For the addition problem, the examiner showed a card with one ice cream cone in the upper center, two in the lower left corner, and three in the lower right corner. Then, the examiner said (in Spanish): "Look, I had one ice cream cone and I got another. How many do I have now? These (pointing to the lower left corner) or these (pointing to lower right corner)?" The maximum possible score in this subtest was two.

Procedure

Children were administered the Numerical Abilities Test as part of a larger neuropsychological battery for Spanish speakers, ENI-P (Matute et al., in press). This article refers only to the analysis of the numerical abilities domain.

Parents of all children gave written informed consent and were asked to complete a demographic and clinical history questionnaire adapted from the *Evaluación Neuropsicológica Infantil* (Matute, Rosselli, Ardila, & Ostrosky, 2007). Trained psychologists conducted children's evaluations and parental interviews in a spacious, well-lit room, free of distractions, at the preschool or the child's home. The duration of the parental interview was 30 minutes, and that of the child assessment sessions was approximately 2 hours, divided into three sessions. Subtests were presented in a counterbalanced manner. All numerical subtests were applied in the same session.

To determine the test-retest reliability, we evaluated 60 children (mean age = 43.25 months, $SD = 8.41$, age range = 30–58 months) from the total sample, within a test–retest interval of 15 days. These children were randomly selected and were evaluated in the same location as their first assessment.

Data analysis

We obtained raw scores for all the subtests, and then calculated the internal consistency for each using Cronbach's alpha analysis. Using the raw scores obtained in the test and retest evaluation of sixty children, we performed Pearson correlations to determine the test–retest reliability.

To evaluate the effect of Age (five groups), Sex (male and female), Maternal Education (low and high), and School Attendance (public, private, and no preschool) on children's performance, we performed a four-way MANOVA on the raw scores of the four subtests. As a first step, in order to test the MANOVA assumption of correlation between the dependent variables, we performed a series of Pearson correlations with the raw scores of the four subtests. The second step was to introduce these scores as dependent variables of the MANOVA. In the third step we conducted a series of follow-up ANOVAs only for the main effects encountered, in order to determine specific effects on each subtest. Finally, to determine mean differences across groups, we performed Bonferroni-corrected post hoc comparisons.

Results

Reliability

The overall internal consistency of the Numerical Abilities test was Cronbach's $\alpha = .951$. Internal consistency for each subtest was as follows: Magnitude Comparison (Cronbach's $\alpha = .758$), Counting (Cronbach's $\alpha = 956$),

Table 3. Pearson's correlations among the mathematical abilities subtests and test–retest correlations.

	1.	2.	3.	4.	Retest[a]
1. Magnitude comparison	1.000				.776**
2. Counting	.565**	1.000			.843**
3. Subitizing	.550**	.804**	1.000		.680**
4. Basic calculation	.456**	.469**	.533**	1.000	.396**

Note. [a]$N = 60$. **$p < .01$.

Table 4. Mean raw scores (*SD*) of early numerical subtests as a function of age group.

		Age groups (years)						
		2;06–2;11	3;00–3;05	3;06–3;11	4;00–4;05	4;06–4;11		
	Maximum score	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	$F(4,262)$	η_p^2
Magnitude comparison	7	2.8 (2.19)	4.59 (1.53)	4.87 (1.5)	5.59 (1.11)	5.82 (1.2)	18.95***	.22
Counting	12	2.7 (2.96)	4.63 (4.05)	7.87 (4.23)	9.33 (3.61)	11.24 (1.86)	25.02***	.27
Subitizing	5	1.32 (1.43)	2.13 (1.83)	3.45 (1.79)	4.05 (1.39)	4.45 (1.13)	17.75***	.21
Basic calculation	2	0.33 (0.56)	0.59 (0.68)	0.90 (0.7)	1.11 (0.82	1.22 (0.83)	5.56***	.08

Note. ***$p < .001$.

Subitizing (Cronbach's $\alpha = .884$), and Basic Calculation (Cronbach's $\alpha = .481$). These values indicate that internal consistency for the Magnitude Comparison, Counting, and Subitizing Subtests is good; the basic Calculation Subtest, however, showed a low internal consistency, according to Field's (2005) criteria.

In the test-retest reliability analyses, the correlation coefficients ranged from medium (.39) to high (.84) in strength (see Table 3), suggesting that reliability was appropriate.

Age, maternal education, school attendance, and sex effects

The MANOVA yielded two main effects: Age Group (Pillai's Trace = .38, $F(16,1048) = 6.96$, $p < .001$,

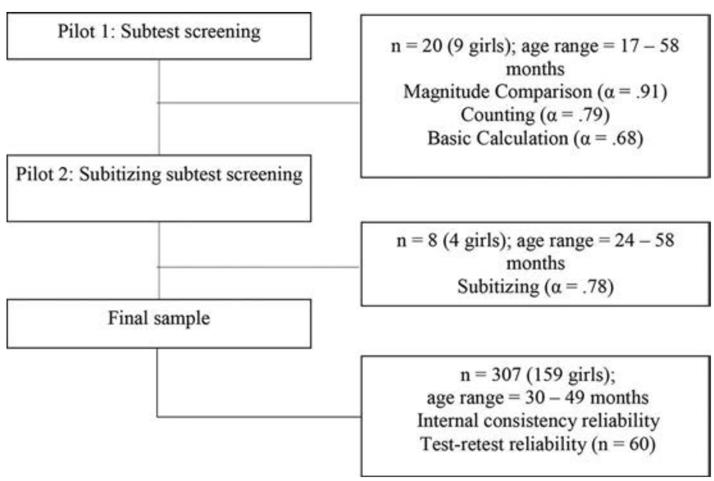

Figure 1. Flow chart of assessment tool development.

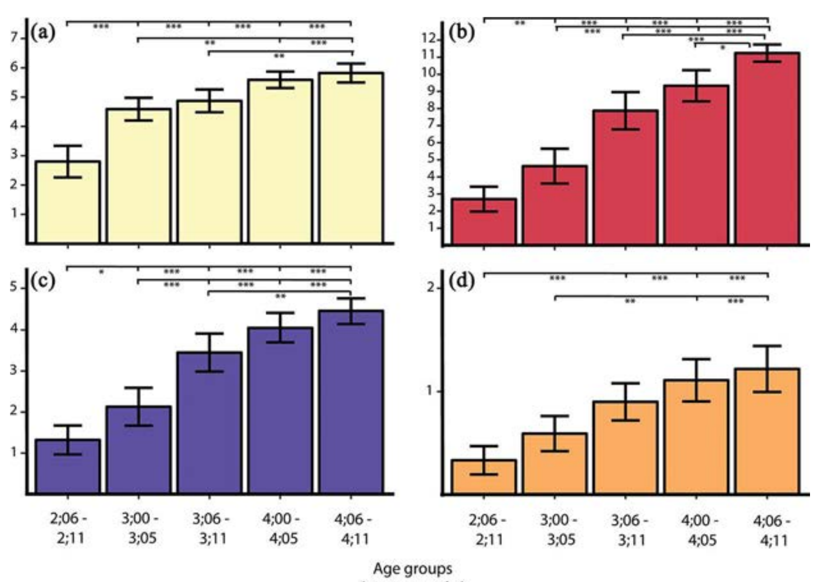

Figure 2. Children's mean raw scores (±2 SE) in the (a) magnitude comparison subtest, (b) counting subtest, (c) subitizing subtest, and (d) basic calculation subtest. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5. Mean raw scores (*SD*) of early numerical subtests as a function of maternal education.

Subtest	Maximum score	Maternal education: Low *M*(*SD*)	Maternal education: High *M*(*SD*)	*F* (1,262)	η^2_p
Magnitude comparison	7	4.00 (1.98)	4.82 (1.85)	6.58*	.02
Counting	12	5.49 (4.65)	7.30 (4.59)	8.47**	.03
Subitizing	5	2.31 (1.98)	3.16 (1.90)	6.96**	.02
Basic calculation	2	0.69 (0.76)	0.84 (0.79)	0.40	.00

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

$p\eta^2 = .096$) and Maternal Education (Pillai's Trace = .051, $F(4,259) = 3.48$, $p = .009$, $p\eta^2 = .051$). No other main effects or significant interactions were found (Sex, Pillai's Trace = .008, $F(4,259) = 0.52$, $p = .71$, $p\eta^2 = .008$; School Attendance, Pillai's Trace = .030, $F(8,520) = 0.99$, $p = .43$, $p\eta^2 = .01$). The four follow-up ANOVAs with Age Group as between-subjects factor and children's scores on each of the four subtests as dependent variables were significant (see Table 4 for detailed statistics). The effect sizes of these ANOVAs ranged from medium to large. As seen in Figure 2, the Bonferroni-corrected post hoc comparisons showed three general patterns: (a) In all subtests, except in Basic Calculation, there were significant differences between the two youngest groups; (b) in all subtests, except in Counting, children of the two oldest groups performed similarly; and (c) differences in children's performance were more likely to be found in non-adjacent groups. Finally, the Counting Subtest was the most sensitive to differences in children's performance across groups. The ANOVAs with Maternal Education as between-subjects factor were significant for the Magnitude Comparison, Counting, and Subitizing Subtests, showing that in these subtests, children in the high Maternal Education group outperformed those in the low Maternal Education group. Nevertheless, size effects were small. See Table 5 for detailed statistics.

Discussion

A number of studies have reported that early numerical abilities have a great impact not only on later mathematical knowledge, but also on later academic performance in general (Duncan et al., 2007). These reports underscore the need for norm-referenced assessments that can determine whether children's performance is like that of other children of the same age. This article presents an instrument for assessing the early numerical abilities of Spanish-speaking children living in Mexico: the Numerical Abilities test of the *Evaluación Neuropsicológica Infantil-Preescolar* (ENI-P; Matute et al., in press). The test includes a set of subtests employing tasks comparable to those in education psychology studies (Jordan et al., 2007; Jordan et al., 2006) and batteries developed in other countries (Bracken, 2006; Ginsburg & Baroody, 2003; Grégoire, Nöel, & Van Nieuwenhoven, 2015), with appropriate internal and test–retest reliability. We also investigated how variables such as age, school attendance, maternal education, and sex affected children's performance. In the following sections we discuss our outcomes.

Age

The subtests included in the Numerical Abilities Test captured development across the different age groups, as shown by the significant age effect on all subtests. The most sensitive measure (i.e., the one in which we encountered more differences between adjacent groups) was the Counting Subtest. This subtest captured the development in children's ability to count that has been reported in previous studies (Wynn, 1992). Children go from reciting only a few number words to following the How-to-Count principles: They recite the count list up to ten in a stable manner, point to each element of the set, and indicate its cardinality.

Children's performance differed across the age groups in the Magnitude Comparison Subtest; however, significant differences were found only between non-adjacent groups. Similar results have been reported by Halberda and colleagues; in their cross-sectional studies, these authors found differences in the ability of children aged three to six to compare numerical and non-numerical quantities (Halberda & Feigenson, 2008; Odic, Libertus, Feigenson, & Halberda, 2013), while their longitudinal studies found no improvements in preschoolers' performance in evaluations at intervals of six months (Shusterman, Slusser, Halberda, & Odic, 2016). Although changes in infants' performance comparing magnitudes can be found over periods of six months, our results, along with the aforementioned studies, suggest that in early childhood (from 2 years 6 months to 4 years 11 months) changes can be found over periods of 1 year.

Developmental changes in children's ability to subitize have received minimal attention. Starkey and Cooper (1995) asked three- and four-year-old children to say how many dots they saw using dot collections of 1 to 7. Their results showed no differences in accuracy between the two age groups for numerosities ranging from 1 to 4 and only a marginal difference for 5. In the current study, we found differences in the ability to subitize collections of dots ranging from 1 to 5 among the three youngest groups (2;06–2;11, 3;00–3;05, and 3;06–3;11), suggesting that developmental differences can be found at early ages. The lack of differences between the two oldest groups might reflect a near-perfect performance in numerosities from 1 to 4, similar to the results of Starkey and Cooper.

Of the four numerical abilities evaluated in our study, basic arithmetic appears latest in development. Huttenlocher et al. (1994) found that half of the children between 2 years 6 months and 3 years of age had zero correct responses in an addition/subtraction task. Even their oldest group (3 years 9 months to 3 years 11 months of age) answered only half of the trials correctly. Our results are consistent with this finding; in general, the two youngest groups did not have any correct responses, while the three oldest groups had an average of one.

School attendance

Our results showed that children's performance was similar, regardless of whether they attended a private or public preschool, or did not attend at all. However, it should be kept in mind that in an effort to reflect children's rate of preschool attendance in Mexico, the sample was constructed with only a small percentage that did not attend (9.4%). The lack of difference in numerical skills probably reflects the results of the comparison between children attending public versus private preschools, with little effect from children who did not attend preschool at all.

Other studies have found that children's numeracy skills vary according to certain features of the preschool they attend. Anders et al. (2012) investigated the effect of preschool environments, among other variables, on three-year-olds' scores on a standardized arithmetic subscale. The authors found that the child-staff ratio and amount of space per child were related to better performance on the standardized subscale. It is thus possible that more fine-grained measures of preschool environments would show greater differences.

Maternal education

Our results show that maternal education has a small but significant impact on children's performance in numerical ability subtests: Children of mothers whose education was below the national mean of 9 years performed below those of mothers above the mean in all subtests except Basic Calculation. Hackman and Farah's (2008) review highlights the effects of maternal education on cognitive domains—language, executive functions, and memory—in preschoolers and in older children, and there are similar effects on the numerical domain (Jordan, Kaplan, Ramineni, & Locuniak, 2009). These effects in math performance could be mediated by language performance or by parenting characteristics. For example, SES effects are greater on verbal than non-verbal aspects of mathematics (Jordan, Huttenlocher, & Levine, 1992). Indeed, in the subtest showing no differences related to maternal education, Basic Calculation, the solution was visually presented. Parenting characteristics that are more common in middle-SES than in low-SES parents may also play a role. Gunderson and Levine (2011) found that parents' SES—an index composed of family income and primary caregivers' years of education—was associated with the number of times parents counted or named the numerosity of the objects presented.

Finally, one interesting finding of our study was the effect of maternal education on children's performance in the Magnitude Comparison Subtest. A possible explanation for this effect is that these differences are mediated by children's understanding of numerical quantifiers or adjectives related to size. Further studies are needed to support this explanation.

Sex differences

Preschool boys and girls performed similarly in all subtests in this study. Previous studies have reported that boys outperform girls; however, the differences are small in explaining individual differences in mathematical achievement in preschool Melhuish et al. (2008). Sex differences have also been reported at later ages. Rosselli, Ardila, Matute, and Inozemtseva (2009) found that boys outperformed girls in two mathematical tasks, mental math and arithmetical problems. Importantly, boys' greater performance in the arithmetical problems task was found in the age range of 13–16 years, but not in the 7–10 age range. Taken together, these two results suggest the possibility of sex differences at later stages of development.

Limitations

A limitation of the current study is that although the Cronbach's alpha value of the Basic Calculation Subtest was appropriate in the pilot study, in the final sample it was low; nevertheless, its test–retest reliability was appropriate. There are two possible reasons for this low value. First, although there were no sociodemographic differences between the age groups in Pilot 1, there were differences between the Pilot 1 sample and the final sample in the proportions of children who attended private and public preschools, or who attended no preschool. The difference in developmental times for the acquisition of addition and subtraction could also explain the low value in this subtest (Shinskey, Chan, Coleman, Moxom, & Yamamoto, 2009). Finally, in order to strengthen the results regarding the effects of school attendance, a larger sample is needed of children who do not attend preschool.

General conclusions

In summary, these findings suggest that the Numerical Abilities test of the ENI-P (Matute et al., in press) can be considered a reliable instrument for the assessment of numerical abilities in Spanish-speaking Mexican preschoolers. It can be used to track the typical development of numerical abilities; however, as with every new assessment tool, further research is needed to determine its predictive value, sensitivity, and specificity in detecting children at risk of developing learning disabilities. Maternal education and children's age should be considered in these evaluations.

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