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Understanding sources of individual variability in parents' number talk with young children

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A B S T R A C T

Several studies suggest that parents' use of number words while talking with their children is positively related to children's understanding of certain mathematical concepts. In this study, we extended these findings and further examined several parent characteristics that could be related to individual differences in their number talk, including their subjective ratings of their math skills, preference for using math, beliefs about the importance of their children's math skills, and numerical approximation abilities, an early number skill present in children and adults. A sample of 44 5- and 6-year-old children and their parents completed a variety of laboratory-based tasks, including a 10-min free play session to assess number talk, a standardized math assessment for children, a nonsymbolic numerical comparison task for parents, and several questionnaires for parents. Parents' overall number talk was not related to children's performance on the math assessment; however, parents' use of numbers larger than 10 was positively and significantly related to children's math abilities even when controlling for parents' overall talk. Parents' large number talk was also associated with their numerical approximation abilities and subjective math ability, suggesting that math-specific characteristics of parents themselves can explain some of the individual variability in parents' use of number words, especially those larger than 10.

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Introduction

Remarkable individual differences in children's early math abilities are present even before children begin formal schooling. Although most preschoolers are able to count to 10, some children can count to over 100, whereas others struggle to count beyond 3 or 4 (Aubrey, 1997; Sarama & Clements, 2009). In addition, approximately 5% of children starting kindergarten can solve problems involving numbers, whereas another 15% do not understand relative quantities (Bassok & Latham, 2014; Zill & West, 2001). These early individual differences in math ability predict the level of math achievement in elementary and middle school as well as the rate of growth across these years (Bodovski & Farkas, 2007; Denton & West, 2002; Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Compared with reading abilities, attention, and socioemotional competence, children's math abilities at the start of school are among the strongest predictors of later reading and math achievement (Duncan et al., 2007). Thus, it seems that early math abilities are important for children's later learning, yet all children do not enter school with the same competencies.

Abundant research has addressed factors that can promote these crucial early skills. Children's general cognitive abilities, including visual–spatial skills, working memory, and inhibitory control, as well as their math-specific cognitive skills, such as estimation abilities, appear to be relatively important for developing early numeracy skills (Assel, Landry, Swank, Smith, & Steelman, 2003; Bull & Scerif, 2001; Espy et al., 2004; Keller & Libertus, 2015; Libertus, Feigenson, & Halberda, 2011; Libertus, Feigenson, & Halberda, 2013; Mazzocco, Feigenson, & Halberda, 2011; Raghubar, Barnes, & Hecht, 2010). In addition to these individual characteristics, numerous contextual processes in the home and school are related to children's early math skills, including but not limited to exposure to high-quality child care, time spent on mathematics in the classroom, parent socialization practices, and participation in math activities in the home (Bodovski & Farkas, 2007; Dearing, McCartney, & Taylor, 2013; LeFevre et al., 2009; Melhuish et al., 2008; Simpkins, Davis-Kean, & Eccles, 2005). In this study, we focused on one specific aspect of parenting, namely parents' discussion of numbers during informal play with their children, as a predictor of children's early math abilities.

Number talk and children's early math abilities

Previous research has revealed that the quantity and quality of number-related input (referred to as "number talk" hereafter) provided to young children positively relates to their growth in math knowledge (Boonen, Kolkman, & Kroesbergen, 2011; Gunderson & Levine, 2011; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010). Parents vary significantly in their amount of number talk, and this individual variability is related to children's number knowledge. Specifically, Levine and colleagues (2010) found wide variation in the frequency of number talk heard by 14- to 30-month-olds during everyday activities in the home, ranging from less than 30 to nearly 1800 number words a week. Importantly, they showed that the amount of parental number talk was positively correlated with children's understanding of the cardinal meaning of number words at age 46 months. These associations persisted when accounting for children's number talk, suggesting that the relation between parents' number talk and children's math skills is not attributable to children with stronger math skills eliciting more number talk from their parents. In a more detailed follow-up analysis of the data, Gunderson and Levine (2011) showed that parent number talk involving quantities larger than 3 predicted children's cardinal meaning knowledge of both small (<4) and large ($\geq$4) numbers. These relations held even when controlling for socioeconomic status (SES) and did not extend to children's receptive vocabulary. Thus, there is reason to believe that parents' number talk is related to children's math abilities, although previous work has been limited to a single mathematical principle (i.e., cardinality) during early childhood.

Sources of individual differences in parent number talk

As reviewed above, evidence suggests that parent number talk is positively and significantly related to young children's math abilities. However, it remains unknown why some parents talk more about numbers with their children than do others. Several characteristics of parents could theoretically explain some of this variability. Specifically, the current study investigated whether differences in parent number talk are related to parents' beliefs about their own math skills, their beliefs about their children's math skills, or their number-specific competence, that is, the acuity of their approximate number system (ANS).

One potential factor that could predict parents' number talk in the home is their own math ability, including their beliefs about their abilities and the importance of math more broadly. Although parents' educational attainment appears to foster home learning activities that support children's early math skills (e.g., Zadeh, Farnia, & Ungerleider, 2010), less is known about how parents' math abilities may be related to their behaviors to support children's math or, specifically, their use of number words. Some evidence suggests that parents' beliefs about math, such as their own skill level (i.e., their subjective ratings of their ability) and the importance of math (i.e., their preference for math), predict their reports of math activities in the home (Missall, Hojnoski, Caskie, & Repasky, 2014). In addition, parents' participation in math and science activities independently (i.e., without their children) appears to be related to participation in math and science activities with their children (Simpkins et al., 2005), suggesting that parents who are more comfortable with math and use math more frequently engage in more math-related activities with their children. As such, in the current study, we directly addressed whether parents' subjective math ability and preference for math predict number talk with their children.

Parents who value the importance of early math skills for their children may also be more likely to use numbers when playing with their children. Given the limited information that is often provided to parents of children entering kindergarten (Piotrkowski, Botsko, & Matthews, 2000), significant variability exists in parents' beliefs about what skills children need when starting kindergarten. Although no research to date has addressed how parents' beliefs about early math learning are related to their number talk in particular, these beliefs do appear to be related to parents' practices more broadly. Parents who valued the importance of their children learning math at a young age were more likely to report engaging in math-related activities with their children in the home (Sonnenschein et al., 2012). In addition, DeFlorio and Beliakoff (2014) found that parents' beliefs about the mathematical knowledge of 5-year-olds and the accuracy of those beliefs predicted children's mathematical ability over and above children's age and SES (but see LeFevre et al., 2009). Thus, parents' beliefs about early math skills may also be related to their number talk.

Finally, parents' numerical estimation abilities may also predict their use of number talk with their children. Growing evidence suggests that basic numerical processing abilities are an important contributing factor to mathematical ability. Numerical information can be represented in an approximate format using a basic system that is shared with animals and preverbal infants. These representations are thought to rely on the ANS, which allows for quick estimations and comparisons of approximate quantities (Dehaene, 1997). It is well established that performance on number comparison tasks that require approximations of quantities obeys Weber's law—that is, performance depends on the ratio between the numbers to be compared—and that people differ in their number comparison abilities (Dehaene, 1992; Halberda, Ly, Wilmer, Naiman, & Germine, 2012; Moyer & Landauer, 1967). Importantly, these individual differences in approximation skills are related to mathematical abilities; the more precisely children and adults are at making rapid approximate numerical comparisons, the better they tend to perform on standardized math tests (for reviews, see Chen & Li, 2014; Fazio, Bailey, Thompson, & Siegler, 2014; Feigenson, Libertus, & Halberda, 2013). In addition to parents' math abilities, parents' ANS acuity may also be related to their number talk with their children. In a previous study, it was shown that parents' ANS acuity predicted a specific aspect of children's math ability, namely children's ability to solve applied math problems (Braham & Libertus, 2016). One possible explanation is that parents with greater ANS acuity may create different home learning environments and more opportunities to learn about math in everyday contexts that in turn shape differences in children's abilities to solve applied math problems. Here, we explored this possibility as well as other potential characteristics of parents that may be related to the amount of number talk used with their children.

The current study

Past research suggests that parents' discussion of numbers predicts young children's math skills. In this study, our first goal was to replicate these findings among a sample of kindergarteners and to examine whether number talk is important for children's math abilities more broadly. The second goal of this study was to examine parental characteristics that could explain individual variability in parent number talk. Specifically, we were interested in whether parents' subjective ratings of their math abilities, preference for math, beliefs about the importance of their children developing certain math skills, or ANS acuity could predict their use of number words when interacting with their children.

Method

Participants

A sample of 54 children (23 girls) and their parents (44 mothers and 8 fathers) participated in this study. Due to the low number of fathers, a direct comparison between mothers and fathers could not be made. Because research suggests that mothers and fathers may interact differently with their children (e.g., Laflamme, Pomerleau, & Malcuit, 2002; Lindsey, Cremeens, & Caldera, 2010), we focused exclusively on mother–child dyads (N = 46; 20 girls).[1] Children and parents were recruited from a medium-sized U.S. city through a university participant registry, flyers in local libraries, playgrounds, museums, and the like as well as through advertising at family-friendly events in the community. Informed written consent was obtained from all parents prior to the study.

Children were 5 or 6 years of age (M = 5 years 9.55 months, SD = 7.57 months) and were primarily White (89%). Mothers were between 26 and 45 years of age (M = 36.40 years, SD = 4.89). On average, mothers were highly educated, with most mothers (89%) having at least a bachelor's degree. Most mothers (73%) reported that their children were exposed to only English in the home. Spanish was the most common second language and was reported by 19% of parents. In bilingual households, all children were exposed to English at least 70% of the time aside from one child who was exposed to Hindi 80% of the time and English the remaining 20% of the time. In terms of birth order and sibling status, 18% of children were only children, 48% had one sibling (20% of children in the sample were the oldest of the two children), 18% had two siblings (11% were the oldest of the three children and 5% were the second born), and 16% had three or more siblings (7% were the first born of four or more children and 5% were the second born).

Procedure

Children and their parents came to the laboratory for a single session lasting approximately 1 h to complete all tasks. After informed consent was obtained, parent–child dyads played freely with several age-appropriate toys alone in a quiet room for approximately 10 min. Following this play session, children completed the Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003) while parents completed a nonsymbolic number comparison task as well as several questionnaires about their views toward math. Children received a small prize (stuffed animal, lunch box, or book) to thank them for their participation, and parents received $8.

Measures

Parents' number talk

Parents were instructed to play with their children as they normally would at home and were provided with a set of toys, including a picture book, a book about emotions and a set of accompanying

[1] This sample included two sets of siblings (two children each). The two parents both completed a free play session with each child separately and so are included in our analyses. When one child from each pair was excluded (all possible combinations of which were tested), patterns of significance did not differ from what is presented here.

egg faces displaying the different emotions mentioned in the story, play food and dishes, paper and colored pencils, animal puppets, a balancing game, a set of toy vehicles, and a cash register with pretend money. Parents and children were left alone in a small room to play for approximately 10 min. All interactions were video-recorded with a webcam connected to a computer that was hidden behind a curtain.

All videos were later coded by trained research assistants using ELAN Linguistic Annotator Version 4.8.0 (http://tla.mpi.nl/tools/tla-tools/elan/; Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). For the purposes of this study and in accordance with previous work (Levine et al., 2010), we coded parents' number word use. We excluded utterances such as "I want to play with this one" from our analyses because the word "one" was not used in the numeric sense. Children's number word use was coded in the same manner.

Three research assistants coded all videos included in this sample for number talk. Five videos were triple-coded by all three coders with extremely high reliability of the overall count of number words used by parents and children among coders (adjusted interclass correlation coefficients = .996 and .979, respectively). For videos that were triple-coded, the average count was used across the coders.

Finally, the total numbers of words spoken by both parents and children were calculated to derive the proportion of words that were number words used by parents and children. All videos were transcribed by one of nine trained research assistants. Each transcription was verified by a second research assistant and then analyzed to determine the total amount of all words spoken by the parents and children. We then calculated the proportion of words that were number words by dividing the amount of number words by the total amount of words used by parents and children. We also calculated proportion scores for small (1–5), medium (6–10), and large (>10) numbers separately. Proportion scores were used in all analyses rather than raw counts of number words to adjust for differences in overall talk, but findings are consistent when analyzing the frequency of number talk as well.

Parents' ANS acuity

To assess acuity of the ANS, parents completed a nonsymbolic number comparison task similar to that used by Halberda, Mazzocco, and Feigenson (2008). Parents were shown sets of yellow and blue dots and, for each display, were asked to report which color was more numerous. In each image, yellow dots appeared on the left half of the screen and blue dots appeared on the right half of the screen. Orthogonally, in half of the trials the yellow dots were more numerous, and in the other half the blue dots were more numerous. In one third of all trials, the average dot size was held constant between the two colors, such that the more numerous dots also had more overall surface area (i.e., numerosity and surface area were correlated). Alternatively, in an additional third of all trials, the total surface area was held constant across the blue and yellow dots. In the final third of trials, the total perimeter was held constant; that is, the dots on the more numerous side of the display took up less overall surface area than the dots on the less numerous side (i.e., numerosity and surface area were anti-correlated). These perceptual controls were included to ensure that parents relied on numerosity rather than other visual cues during this task (Halberda et al., 2008). For all trials, dot size was on average 36 pixels in diameter and varied within sets (allowed variation = 20%). Stimuli were displayed for 1500 ms on a 23-inch computer monitor, followed by a blank screen until parents responded. The number of dots in each set ranged from 12 to 36.

Researchers introduced the task to parents and instructed them to respond as quickly and accurately as possible for each trial by pressing one of two keys on a keyboard labeled with yellow and blue stickers. Parents completed 4 practice trials with preselected stimuli presented in a random order, followed by 150 test trials, including 30 trials for each of the following ratios between the lower and higher number of dots in a random order: 3:4 (e.g., 24 and 32 dots), 4:5 (e.g., 24 and 30 dots), 5:6 (e.g., 25 and 30 dots), 7:8 (e.g., 21 and 24 dots), and 9:10 (e.g., 27 and 30 dots). Performance on the nonsymbolic number comparison task was quantified as the percentage of correct responses across all trials given evidence that accuracy is the most reliable indicator of performance on these tasks (Inglis & Gilmore, 2014).

Parents' subjective math ability and math preference

Parents also completed a self-report measure of numerical aptitude and preference for numerical information, the Subjective Numeracy Scale (Fagerlin et al., 2007). On this measure, parents used a 6-point scale to rate their numerical ability in various contexts (e.g., "How good are you at figuring out how much a shirt will cost if it is 25% off?") and their preference for the presentation of numerical information (e.g., "When reading the newspaper, how helpful do you find tables and graphs that are parts of a story?"). Four items addressing parents' ratings of their math abilities were averaged to create a subjective ability composite (α = .96), and three items representing parents' ratings of their preference for using numbers were averaged to create a subjective preference composite (α = .68). The subjective preference scale initially included one item that did not correlate with responses on other items (α = .26 with this item included) that was excluded in this composite. Both subjective ability and subjective preference subscales, as well as overall scores on the Subjective Numeracy Scale, were previously found to correlate highly with objective measures of numeracy (Fagerlin et al., 2007; Lipkus, Samsa, & Rimer, 2001).

Parents' early math beliefs

To measure parents' academic expectations for their children, parents completed the mathematics portion of the academic benchmarks section of the home numeracy questionnaire used by LeFevre and colleagues (2009). The measure asked parents to rate how important they believed it was for their children to reach each of four math-related benchmarks prior to entering kindergarten (e.g., "Count to 10") on a 5-point scale. The ratings were averaged to derive a total score (α = .72).

Children's math ability

We administered Form A of the TEMA-3 (Ginsburg & Baroody, 2003). The TEMA-3 measures numbering skills (e.g., verbally counting the number of objects on a page), number comparison facility (e.g., determining which of two spoken number words is larger), numeral literacy (e.g., reading Arabic numerals), mastery of number facts (e.g., retrieving multiplication facts), calculation skills (e.g., solving mental and written arithmetic problems), and number concepts (e.g., answering how many tens are in one hundred). The TEMA-3 has been normed for children between the ages of 3 years 0 months and 8 years 11 months. Children's raw scores on the TEMA-3 were converted to standardized math ability scores.

Results

Data analyses and descriptive statistics

One parent failed to complete the nonsymbolic number comparison task, and one additional dyad did not have valid data from the free play session, resulting in a final sample of 44 parent–child pairs. Descriptive statistics for all variables used in this study are shown in Table 1. The total number of words used by parents and children were not related, $r(42) = -.19$, $p = .21$. As can be seen in Table 2, however, parent number talk and child number talk, measured as the proportion of talk that included number words, were significantly correlated.

Relations between parents' number talk and children's math abilities

To assess whether parents' number talk was correlated with children's math abilities, we first correlated the proportion of parent words that were number words with children's standard scores on the TEMA-3. As can be seen in Table 2, this correlation between parents' overall number talk and children's math ability was not significant. We then further probed these relations by examining parents' number talk separately for small, medium, and large numbers. Although children's math abilities were not significantly related to parents' number talk in the small and medium number range at the bivariate level, a positive association emerged between parents' use of numbers larger than 10 and children's math abilities (see Fig. 1).

Table 1
Descriptive statistics for parent and child number talk, parent cognitive factors, and child math ability ($N = 44$).

Variable	*M* (*SD*)
Parent number talk	13.89 (15.19)
Numbers 1 to 5	7.34 (8.37)
Numbers 6 to 10	3.53 (5.62)
Numbers larger than 10	3.02 (4.01)
Parent total talk	746.64 (233.53)
Parent number talk/parent total talk	0.02 (0.02)
Numbers 1 to 5	0.01 (0.01)
Numbers 6 to 10	0.004 (0.01)
Numbers larger than 10	0.004 (0.004)
Child number talk	12.89 (11.05)
Numbers 1 to 5	7.51 (7.35)
Numbers 6 to 10	2.90 (4.13)
Numbers larger than 10	2.48 (3.86)
Child total talk	393.68 (121.11)
Child number talk/child total talk	0.03 (0.03)
Numbers 1 to 5	0.02 (0.02)
Numbers 6 to 10	0.01 (0.01)
Numbers larger than 10	0.01 (0.01)
Parent ANS acuity (% correct)	80.48 (6.20)
Parent subjective math ability (6-point scale)	4.32 (1.33)
Parent subjective math preference (6-point scale)	4.53 (0.88)
Parent early math beliefs (5-point scale)	3.06 (0.67)
Child math ability (standardized score)	111.89 (16.57)

Table 2
Correlations between proportions of words that were number words, including overall number talk and ranges of numbers, for both parents and children, parents' cognitive factors, and children's math ability.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Parent overall number talk	–											
2. Parent number talk (1–5)	.90***	–										
3. Parent number talk (6–10)	.76***	.48**	–									
4. Parent number talk (11+)	.71***	.52***	.36*	–								
5. Child overall number talk	.60***	.49**	.48**	.45**	–							
6. Child number talk (1–5)	.47**	.55***	.17	.35*	.78***	–						
7. Child number talk (6–10)	.36*	.12	.63***	.18	.63***	.16	–					
8. Child number talk (11+)	.39**	.25	.28	.53***	.64***	.22	.29†	–				
9. Parent ANS acuity	.32*	.18	.37*	.30†	.44**	.28†	.30†	.36*	–			
10. Parent subjective ability	.18	.11	.11	.27†	−.06	−.13	−.03	.08	.11	–		
11. Parent subjective preference	.29†	.24	.28†	.14	.12	.06	.12	.08	.21	.51***	–	
12. Parent early math beliefs	.02	.06	−.10	.06	−.15	−.06	−.24	−.02	.13	.18	−.09	–
13. Child math ability	.16	.13	−.04	.39**	.22	.22	−.03	.25†	.23	−.01	−.15	.31*

Note. $df = 42$. ANS, approximate number system.
† $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

To examine whether use of large number words was uniquely related to children's math abilities, math ability was also regressed on the proportion scores for each number range (i.e., how many of the parents' words were small, medium, and large numbers out of the total number of words used; see Table 3). This model was significant overall, $F(3, 40) = 3.15$, $p = .04$, and revealed that only the proportion of words that were numbers larger than 10 uniquely predicted children's math skills. These results persisted when accounting for children's number talk as well, although the overall model

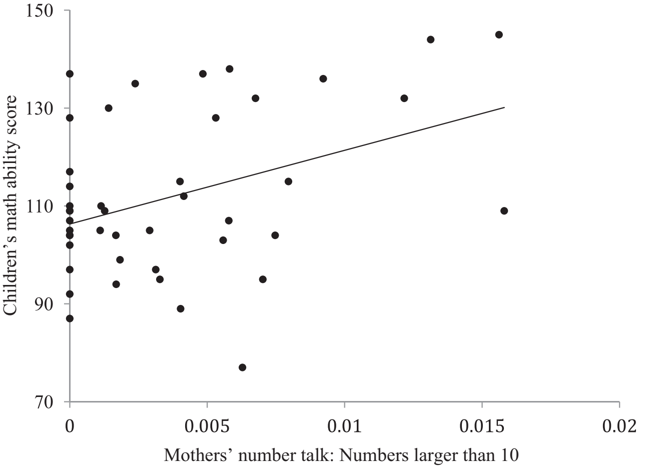

Fig. 1. Scatterplot of the association between proportion of parent talk that contained number words larger than 10 and children's standardized math scores ($r = .39$, $p = .01$).

Table 3
Standardized regression results of children's math ability scores on the TEMA-3 regressed on the proportions of parents' and children's words that were small number words (numbers 1–5), medium number words (numbers 6–10), and large number words (numbers >10).

	β (*SE*)	β (*SE*)
Parent number talk		
Numbers 1 to 5	−0.03 (0.18)	−0.12 (0.22)
Numbers 6 to 10	−0.20 (0.16)	−0.16 (0.23)
Numbers larger than 10	0.48** (0.17)	0.42* (0.20)
Child number talk		
Numbers 1 to 5		0.15 (0.18)
Numbers 6 to 10		−0.04 (0.21)
Numbers larger than 10		0.08 (0.18)

Note. $R^2 = .19$ in middle column; $R^2 = .21$ in right column. TEMA-3, Test of Early Mathematics Ability.
* $p < .05$.
** $p < .01$.

was no longer significant, $F(6, 37) = 1.65$, $p = .16$, suggesting that associations were not attributable to children's elicitations of number talk from their parents. For the remaining analyses, we focused primarily on parents' large number word use given this unique relation with children's math scores.

Given the large number of parents who never used large number words, large number use was highly right-skewed (skewness = 1.31). To account for this non-normal distribution, we also treated large number use as a categorical variable in an analysis of variance (ANOVA), thereby avoiding distributional assumptions about large number talk. Large number word use was coded into five categories: whether large number words were never used ($n = 15$), were less than 0.2% of all words (50th percentile, $n = 7$), were less than 0.5% of all words (75th percentile, $n = 8$), were less than 0.9% of all words (90th percentile, $n = 9$), or were more than 0.9% of all words ($n = 5$). We then conducted a one-way ANOVA with children's TEMA-3 scores as the dependent variable and large number category as a between-participants factor and found significant differences in math ability across groups, $F(4, 39) = 2.82$, $p = .04$. In addition, a linear contrast test showed that math ability increased as the binned proportion of large number word use increased, $F(1, 39) = 3.06$, $p = .004$.

To assess which parental characteristics were unique predictors of parents' number talk during free play, large number talk was then regressed on parents' ANS acuity, subjective ability and preference ratings, and early math beliefs. Two data points were identified as having a residual above 2.5 standard deviations from the mean and, thus, were excluded from these analyses. This model was significant overall, $F(4, 37) = 3.06$, $p = .03$ (see Table 4). Both ANS acuity and subjective ability ratings were significant predictors of parents' use of number words larger than 10. However, parents' subjective preference ratings and early math beliefs were unrelated to parents' use of numbers larger than 10. Thus, parents' ANS acuity and subjective ratings of their math ability appear to be unique predictors of large number talk.

Finally, given the non-normal distribution of parents' large number talk, a zero-inflated Poisson regression model with the same predictors as shown in Table 4 was then estimated.[2] These models simultaneously predict a logistic regression model to estimate whether or not any number talk was present and a Poisson regression model to estimate the amount of number talk among dyads in which larger number talk was seen. This model was significant overall, Wald $\chi^2(4) = 17.64$, $p = .001$, and revealed a similar pattern of results to the ordinary least squares regression model (Table 5). Parents' ANS accuracy and subjective math ability were each uniquely related to the amount of large number talk if it occurred; interestingly, these characteristics did not predict whether or not large number talk occurred.

Discussion

This study investigated how parents' number talk with their children during a 10-min free play session was related to children's math abilities and, furthermore, examined several possible predictors of parents' number talk. We found that parents' overall number talk was not significantly related to their children's math abilities, but use of numbers larger than 10 was correlated with children's math scores. In addition, we found that parents' ANS acuity and their subjective ratings of their own math ability were uniquely related to their number talk. These findings suggest that parents' number talk relates to children's early math skills and that the significant variability observed in how much parents talk about numbers with their children is meaningfully related to characteristics of parents themselves.

Associations between parent number talk and children's math ability

The first aim of this study was to replicate and extend past research addressing relations between parents' number talk with their children and children's math learning. Our original hypothesis that the proportion of parents' talk during free play that contained numbers would be correlated with math scores was not supported, but further probing revealed that a specific form of number talk, namely the proportion of words that were numbers larger than 10, was related to children's math abilities. Importantly, these associations were seen when controlling for the total number of words spoken by parents, suggesting that the link between parents' large number talk and children's math abilities cannot be attributed to more general aspects of parents' language with their children. Although the findings regarding large number talk were unexpected, it is not particularly surprising given the skills that are typically developing at this age. As reviewed above, most children are able to count to 10 and recognize these numbers by the time they begin preschool or kindergarten (Aubrey, 1997; Sarama & Clements, 2009; Zill & West, 2001). It is possible that further exposure to these concepts that children have already mastered (i.e., numbers ≤ 10) might not offer any benefit to children. Thus, this correlational evidence suggests that 5- and 6-year-olds' math achievement may be most related to input that aims at the next step in their developmental progression of mathematical understanding (i.e., an understanding of numbers >10). This would suggest that the use of small and medium number words could be related to children's math skills at early stages of development, a claim that future research should address.

[2] Zero-inflated Poisson models are suitable for variables with a large number of values of zero, such as larger number talk, where 15 parents used no large number words.

Table 4
Standardized regression results of the proportion of parents' words used during free play that were number words larger than 10 regressed on parents' ANS acuity, ratings of their subjective math ability and preference for math, and benchmarks for children's math skills.

	β (*SE*)
Parent ANS acuity	0.36* (0.15)
Parent subjective ability	0.39* (0.17)
Parent subjective preference	−0.11 (0.17)
Parent early math beliefs	−0.02 (0.15)

Note. R^2 = .29. ANS, approximate number system.
* $p < .05$.

Table 5
Zero-inflated Poisson regression results of the proportion of parents' words used during free play that were number words larger than 10 regressed on parents' ANS acuity, ratings of their subjective math ability and preference for math, and benchmarks for children's math skills with robust standard errors.

	Logistic regression estimates *B* (*SE*)	Poisson regression estimates *B* (*SE*)
Parent ANS acuity	−0.16 (3.35)	6.42* (2.56)
Parent subjective ability	−0.02 (0.22)	0.41** (0.14)
Parent subjective preference	−0.001(0.21)	−0.15 (0.21)
Parent early math beliefs	−0.01 (0.31)	−0.01 (0.30)
Constant	−28.74*** (3.00)	−12.17*** (2.03)

Note. ANS, approximate number system.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

The interpretation that children benefit most from input that aims at the next step in their developmental progression is consistent with sociocultural constructivist frameworks based in the work of Vygotsky that argue that development is interactive and contextualized, such that learning is most prolific when children interact with more competent individuals at a level above where they could perform individually (e.g., Jaramillo, 1996; John-Steiner & Mahn, 1996). Specifically in the area of math learning, these theories posit that children are active participants in their learning (Cobb, 1994), and so the skills that children bring to the interactions are crucially important. Although the concept of tailoring instruction to children's existing abilities is well integrated into research in the classroom (e.g., Grigorenko & Sternberg, 1998; Lee & Ginsburg, 2007; Seo & Ginsburg, 2003; Steele, 1999), the current study highlights the importance of these principles in the home as well. Given the importance of adjusting language input based on children's current skill level, these findings also imply that parents must have an accurate understanding of children's abilities.

Although past research has addressed how parents' number talk associates with the acquisition of specific skills, such as the cardinality principle (Gunderson & Levine, 2011; Levine et al., 2010), this study is the first to address how parents' number talk may relate to children's mathematical understanding more broadly. Thus, these findings extend the extant literature and establish that parents' number talk is associated with a range of mathematical constructs aside from simply learning the meaning of these number words. In addition, by analyzing the proportion of parents' words that were number words, these analyses account for overall language use, suggesting that number talk in particular drives associations with math skills. Although parental language input is clearly important for children's learning more generally (e.g., Cristofaro & Tamis-LeMonda, 2012; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Pancsofar & Vernon-Feagans, 2006), the current study establishes a unique link between parents' number talk and children's math skills. Furthermore, by controlling for children's number talk, these results suggest that observed associations between parents' number talk and children's math skills are unlikely to be explained by children's elicitations of number talk.

Despite the significance of these findings, several questions remain unanswered and should be addressed in future research. Due to the correlational and cross-sectional nature of this study, it is impossible to determine whether any causal link exists between parents' language input and children's math abilities. Parents may simply discuss large numbers more frequently with children who have a greater understanding of these numbers and avoid discussing these concepts with children who have not yet mastered them. Thus, more research using longitudinal and experimental designs is necessary to establish whether parents' use of large numbers improves children's math abilities at this age.

Predictors of parents' number talk

In addition to understanding links between parents' number talk and children's math abilities, in this study we were also interested in identifying parent characteristics that could explain variability in their large number talk. Parents' ANS acuity and subjective ratings of their own math abilities—but not their preferences for math or beliefs about the importance of their children's early math skills—were unique predictors of large number talk. When parents talked about large numbers, those with greater ANS acuity and greater self-reported math abilities tended to use more large number words.

Past research on the ANS has focused primarily on associations between acuity of the ANS and math abilities. ANS acuity appears to be a small but significant predictor of math skills (Chen & Li, 2014; Fazio et al., 2014; Feigenson et al., 2013). Although much of this work has been done with children (e.g., Bonny & Lourenco, 2013; Libertus et al., 2011; Libertus et al., 2013; Mazzocco et al., 2011; van Marle, Chu, Li, & Geary, 2014), there is also evidence to suggest that acuity of the ANS is linked with adults' math abilities (e.g., DeWind & Brannon, 2012; Guillaume, Nys, Mussolin, & Content, 2013; Halberda et al., 2012; Libertus, Odic, & Halberda, 2012; Lourenco, Bonny, Fernandez, & Rao, 2012; Park & Brannon, 2013). However, aside from some work linking ANS acuity to adults' educational experiences (e.g., Lindskog, Winman, & Juslin, 2014; Piazza, Pica, Izard, Spelke, & Dehaene, 2013), no research to date has addressed how the ANS maybe be related to adults' functioning more broadly. In particular, this study is the first to examine how the ANS may relate to parenting behaviors. Although more work is needed to replicate these findings, the observed associations between acuity of the ANS and parents' number talk suggest that there are important individual differences in parents that are related to their number talk.

Despite the significance of these findings, more work is needed to understand the mechanisms through which the ANS relates to parents' number talk. One potential explanation is parents' ease and comfort with math, given that parents who have more accurate ANS representations may be more comfortable using math, which could explain why these parents talk more about mathematical concepts with their children. Alternatively, associations between ANS acuity and number talk could operate through parents' preference for using numbers. This explanation is purely speculative, but it stands to reason that parents with more accurate ANS representations may be more prone to labeling sets of objects with a number as opposed to a quantifier (e.g., "few," "a lot"), which would result in more number words used in play. Although both mediational pathways seem to be feasible, associations between the ANS and number talk persisted when accounting for parents' subjective math abilities and preferences for math, casting some doubt on these possible explanations. Future studies should use objective and more detailed measures of parents' math abilities and preferences to follow up on these findings.

Another alternative explanation for the associations observed between parent ANS and number talk could lie in children's math abilities. Parents' number talk may be driven by children's math abilities. If this is the case, passive gene–environment interactions may be at play given that the link between parents' ANS and their number talk could be due to the fact that parents with more accurate ANS representations may have children with stronger math skills who elicit more number talk from their parents. Although in this study we found that parents' number talk was uniquely related to math skills after accounting for children's own use of number words, children may elicit parental math talk in other ways that we could not observe in this study. Finally, it is also possible that parents' ANS acuity in this study served as a proxy for children's ANS acuity (see Braham & Libertus, 2016), such that children with more precise ANS representations are exposed to more math talk and have stronger math abilities.

Interestingly, both ANS acuity and subjective math abilities appeared to be particularly predictive of the amount of number talk that occurred during free play rather than whether or not number talk occurred at all, as indicated by our zero-inflated Poisson regression model accounting for the non-normality of parental number talk. This effect was unexpected but could be attributable to differences in the toys with which parents and children played. For example, parents who engaged with toys that were less conducive to mathematical discussions may have used fewer large number words regardless of their ANS acuity and subjective math abilities. For parents who could discuss math concepts in a way that was more organic and relevant to the activities in which they were engaged, however, these cognitive components may have played a role in the extent to which number talk occurred. This hypothesis should be tested in future work, but these findings nonetheless further support the claim that acuity of the ANS and parents' subjective abilities are related to number talk.

Several parental characteristics studied were unrelated to parents' large number talk. Parents' preference for math and their beliefs about the importance of math for their children were unrelated to large number talk in both correlational and regression analyses. These results are somewhat surprising given previous research suggesting that both parents' preference for math and beliefs about early math are related to the amount of math-related activities in the home (Missall et al., 2014; Sonnenschein et al., 2012). Although parents' number talk and math activities in the home are presumably similar in the sense that they should promote children's math learning (e.g., Gunderson & Levine, 2011; LeFevre et al., 2009; Levine et al., 2010; Skwarchuk, 2009), these processes may look very different for parents. In addition to varying methods of measurement (i.e., observational vs. self-report), these practices may also differ in the degree to which parents are aware of their behavior. Engaging in math-related home activities such as board games that involve counting or playing store may be more of a conscious decision than using number words when speaking to children, and so beliefs about math might not be as strongly related to these less intentional practices. Alternatively, parents in this sample might simply have not varied sufficiently in their beliefs or preferences (see Table 1), which could mask potential associations. This is likely, especially given the overall high level of educational attainment of the parents enrolled in this study. Finally, it is possible that parental beliefs might come into play only in later developmental stages or in discussions of more complex mathematical concepts. Parents who are uncomfortable with math or do not consider math to be important may withdraw from more complicated math discussions with their children (e.g., when helping children with homework; see Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015; Skwarchuk, Sowinski, & LeFevre, 2014), but these parents may nonetheless discuss simple concepts such as numbers and counting with their children. However, more research is needed to test these claims.

Finally, although parents' ANS acuity predicted the use of large number words in play and large number use was correlated with children's math abilities, in this sample we did not observe a significant association between parents' ANS acuity and children's math achievement directly. Given that the correlation between parent ANS acuity and child math ability was positive yet nonsignificant, it is possible that this association and larger mediational pathway could be detected in a larger sample with increased power to detect these potentially smaller effects. As such, more work is needed to determine whether there is in fact an association between parents' ANS representations and children's math achievement potentially explained by parent number talk. This research could also help to determine whether links between ANS acuity and number talk persist when holding children's math skills constant.

Limitations and conclusions

Despite the significance of these findings, several limitations warrant our discussion. First, children and parents who participated in this study were primarily White and highly educated. In this study, we did not address the larger sociocultural context in which these families were embedded. Specifically in terms of parents' beliefs about math, most research has been conducted with fairly advantaged U.S. samples, and so the broader cultural and contextual factors that should also be related to parents' behaviors have not been directly addressed (Super & Harkness, 1986). As such, it is unknown how these processes would play out in more diverse sociocultural contexts, although some evidence suggests that parents' beliefs are informed by the larger social context (e.g., Piotrkowski et al., 2000). Similarly, given the low number of fathers who participated in this study, we focused exclusively on mothers and their children. However, future work is needed to determine whether similar processes are at play in father–child interactions around math. In this study we also did not examine the interactional exchanges in which number words occurred, including the nature of the interaction, the activity in which the dyads were engaged, or the way in which numbers were used (e.g., counting, cardinal numbers).

We observed parents' number talk in a laboratory setting while video-recording their interactions, and estimates of number talk may have been somewhat biased. The fact that variability in number talk in the current study paralleled variability previously reported during in-home observations (Levine et al., 2010) somewhat ameliorates this concern. Nevertheless, naturalistic observations of parents' number use at home in conjunction with in-lab assessments should be used in future work to address whether parents' number talk differs by context. Future studies should also aim to use longitudinal and experimental designs to strengthen any potential directional or causal interpretations of these findings.

It is also important to note that, although we see evidence of an association between parents' large number talk and children's math skills in this sample, numerous other contexts could play a role in children's math skills. In fact, all parental talk variables accounted for only 20% of the variance in children's math abilities. Of particular concern is the child-care environment. Data regarding children's child-care arrangements were not collected in this study, but given the relatively high SES of these children, it is likely that many children spent significant time in formal child-care arrangements (Capizzano & Adams, 2003). Math talk in these settings can predict children's math skills (Boonen et al., 2011; Klibanoff et al., 2006). In this study, we focused exclusively on parental influences on children's math skills, but future research should unpack the variability in children's exposure to numerical content across these various settings to gain a more complete picture of how early math skills develop.

Finally, given our measure of math ability in this study, we were unable to tease apart the specific skills that relate to parents' number talk. Although this enabled us to link number talk to a broad array of math skills, further specificity in which skills are and are not related to number talk would provide more detailed information on how these processes operate, especially given that parents may be using these number words in a variety of different ways.

Nonetheless, the findings of the current study suggest that parents' number talk is a significant predictor of children's math skills, especially when this talk is developmentally appropriate. Furthermore, parents' number talk is related to characteristics of parents themselves such as the acuity of the ANS and their beliefs about their own math ability. These findings also extend previous research on the ANS and suggest that this system is important for broader behavior aside from an individual's own math abilities.

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