Parental Math Engagement with Preterm and Full-term Toddlers

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Several studies suggest that children born prematurely disproportionately struggle in math later in life. Additionally, as early math skills at the start of school are strong predictors of later math and reading, a growing body of literature has examined how parental practices that support young children's learning of number concepts at home. This is referred to as the home numeracy environment. In this study, we explore differences in the home numeracy environment by comparing preterm and full-term toddlers. Additionally, we explore how birth status affects counting skills. A sample of 20 2-year-old toddlers and their parents completed a picture description task to assess the frequency of parents' number talk with their children, a counting task for children, and a home numeracy questionnaire for parents. Interestingly, parents of preterm children used more number talk than parents of full-term children; however, parents of preterm children also reported participating in significantly fewer home math activities. Limited evidence of a significant difference between birth status (preterm or full-term) and child's counting skills was found. Overall, these findings illuminate the need to differentiate between different aspects of the home numeracy environment (namely, parental number talk and home math activities) and provide opportunities for future expansion involving answering questions about how parental beliefs about their child's ability may affect the type of engagement children receive.

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Preface

I am filled with gratitude for the incredible support and guidance that I received from my advisor, Melissa Libertus. Without her, this journey would not have been possible. I am also deeply indebted to Alex Silver, whose mentorship, assistance, and kindness have been invaluable. I would also like to profusely thank Shirley Duong and Jessie Ferraro for their help in coding and participant recruitment respectively, as well as the rest of the Kids' Thinking Lab for their unwavering support. A special thanks to my committee members for their time and feedback.

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1.0 Introduction

Our world is filled with numbers. Whether it be following a recipe, choosing which grocery store checkout line to stand in, or monitoring the engagement of our posts on social media, we are constantly evaluating, comparing, and working with numbers. Given how foundational math is to our daily function, math ability is unsurprisingly predictive of later career success (Brijlall & Ivasen, 2022; Maltese & Tai, 2011; Paglin & Rufolo, 1990; Rivera-Batiz, 1992; Rose & Betts, 2004). Prior literature has shown that math proficiency is significantly related to college students' chosen field of study, which directly predicts future earnings (Brijlall & Ivasen, 2022; Paglin & Rufolo, 1990; Thomasian, 2011). Several longitudinal studies have corroborated the link between math competence and better earnings by demonstrating that mathematical abilities are correlated with a higher likelihood of full-time employment and higher salaries (Brijlall & Ivasen, 2022; Rivera-Batiz, 1992; Rose & Betts, 2004). In addition to financial benefits, greater math skills have been shown to be linked with lifelong greater psychological well-being and better mental health especially in women even after controlling for literacy ability (Parsons & Bynner, 2005).

1.1 Individual Differences in Math Ability

The most important thing to consider when adding elements to your ETD, is to aim for consistency. Individual differences in math competence are already present at the start of kindergarten (Sarama & Clements, 2009; Zill & West, 2001). While some preschoolers enter kindergarten without being able to count past four, about one in ten preschoolers can count to 100 (Sarama & Clements, 2009). Furthermore, at the beginning of kindergarten, some students struggle to grasp relative quantities, while one in twenty kindergartners already know how to solve basic addition and subtraction problems (Zill & West, 2001). This early variability in children's math proficiency predicts their later mathematical abilities, as well as academic and career success (Bodovski & Farksas, 2007; Jordan et al., 2007; Trusty et al., 2000). Additionally, when compared to other cognitive skills such as attention and literacy as well as socioemotional skills, several studies found that children's early math skills at the start of school are among the strongest predictors of later math and reading ability, as well as later academic success (Duncan et al., 2007; Duncan & Magnuson 2011). Thus, children who begin kindergarten with a below-average understanding of early math concepts are at a significant disadvantage that may ultimately affect their future success.

1.2 Home Numeracy Environment

To better understand the causes of these individual differences, researchers have investigated a variety of factors that may influence children's early math knowledge. One such factor is the home learning environment. The home learning environment is comprised of many different opportunities that foster children's learning including formal and informal learning activities as well as conversations that parents and children engage in during everyday activities (Lehrl, Evangelou, & Sammons, 2020). For example, the home numeracy environment—characterized by activities such as counting, the use of money, and engaging in other activities involving the use of numbers—has been shown to contribute to the development of children's math skills (Elliott & Bachman, 2018; LeFevre et al., 2009).

Recent literature has heavily focused on gauging the frequency of math-related input while parents are engaging with their children. Specifically, much of this research has centered on parental number talk or the number-related speech parents engage in with their preschoolers. In a seminal study, Levine and colleagues (2010) observed 44 families and their children in their homes for five visits from age 14 months to 30 months. These families participated in over seven and a half hours of observation in which the amount of parental number talk (i.e., any use of the number words "one" through "ten") ranged from 4 to 257 words (Levine et al., 2010). At 46 months of age, the children completed tests that measured their understanding of cardinality. The amount of number talk parents used when their children were between 14 to 30 months was positively and significantly correlated with their children's understanding of cardinality at 46 months even after controlling for covariates such as socioeconomic status. Similar relations between the quantity of parental math talk and children's later math performance have since been documented in other samples (Casey et al., 2018; Ramani et al., 2015; Son & Hur 2020; Susperreguy & Davis-Kean 2016). Additionally, more fine-grained analyses indicate that particular types of number talk, particularly about larger quantities are related to better math performance in older children (Elliott, Braham, & Libertus, 2017; Gunderson & Levine, 2011).

In addition to this observational work, several studies have discovered a causal link between parental number talk and children's number knowledge. In one study, preschool-aged children and their parents played together in a children's museum exhibit (Braham, Libertus, & McCrink, 2018). Parents were randomly assigned to either a numerical or non-numerical prompt for interacting with their children; then, children completed a variety of assessments that measured spontaneous focusing on number (SFON) (Braham, Libertus, & McCrink, 2018)—a variable that has been shown to be highly related to math competency (Edens & Potter, 2013; Hannula, Lepola, & Lehtinen, 2010). It was found that children whose parents were assigned the numerical prompt showed a significantly greater SFON, suggesting that by involving children in discussions about numerical content (in this case shopping for a meal on a budget), parents can help increase a child's tendency to focus on numerical information in other contexts (Braham, Libertus, & McCrink, 2018). These results are corroborated by a later study where researchers manipulated parental number talk by having parents read one of three picture books every day for four weeks to their two- to four-year-old children (Gibson, Gunderson, & Levine, 2020). The three books were created for the study and included a Small Numbers book (using numbers between 1–3), Large Numbers book (using numbers between 4–6), and a control book which was non-numerical. They found that the Small Number books promoted number knowledge significantly more than the control books, but when children had a better starting understanding of number, Large Number books were also beneficial (Gibson, Gunderson, & Levine, 2020). Together, this prior work on the home learning environment as well as the causal relation between parental number talk and math performance has revealed that children's later math skills can be sharpened by the type and frequency of parental math talk in the home.

1.3 Effects of Preterm Birth

Suggestions to improve children's math skills from a young age may be especially impactful for parents of children who are predisposed to struggle in math. Unfortunately, children born preterm tend to fall into this category. Preterm birth is defined as being born before

37 weeks gestational age and contains the sub-categories of moderate or late preterm (32 to 37 weeks gestational age), very preterm (28 to 32 weeks gestational age) and extremely preterm (less than 28 weeks) (World Health Organization, 1970). Several studies have used a variety of different dependent variables associated with improved math performance—namely, approximate number system and SFON (Bonny & Lourenco, 2013; Libertus et al., 2013; Mazzocco, Feigenson, & Halberda, 2011; Starr et al., 2013; vanMarle et al., 2014)—to test very and extremely premature children's math performance as compared to children born full-term (Schneider et al., 2004; Simms et al., 2013; Libertus et al., 2017). These studies have all found that full-term children tend to outperform preterm children in these math-based tasks (Schneider et al., 2004; Simms et al., 2013; Libertus et al., 2017). Most notably, children born extremely preterm had significantly lower ANS acuity than term-born children even when controlling for differences in verbal IQ, perceptual reasoning skills, working memory, and attention (Libertus et al., 2017) and these results extend to older children with samples including children 6.5 years of chronological age (Libertus et al., 2017).

Despite the significance of this disproportionate disadvantage for children born preterm, it is still unclear to what extent environmental influences may play a role. Prior literature has revealed that parents of preterm-born children have significant differences in their parenting styles and behavior. Initially, the parental experience of premature birth was examined through the lens of being an emotional crisis for parents (Caplan, Mason, & Kaplan, 1965). Since this preliminary study, it has been revealed that parents of moderately and very preterm infants are more likely to show parenting practices such as firm control (Hoffenkamp et al., 2015), spoiling, and inconsistent discipline (Miles & Holditch-Davis, 1997). Additionally, in a study, 40 infant-mother dyads were observed during feeding and play times one, two, and three months after their expected date of birth. Full-term infants were only more active than moderately preterm infants prior to four weeks. Despite this, mothers of moderately preterm infants have been shown to hold, smile, and look at their infants less frequently than mothers of full-term infants, as well as engage in less exploratory play even after there was no significant difference in infant activity (Minde, Perrotta, & Marton, 1985).

Parenting differences may be particularly pronounced during infancy, but several studies have shown that many of these patterns continue throughout toddlerhood and into early childhood. When examining the attachment of 12- to 36-month-old children through two home visits, full-term born toddlers had significantly more secure attachments than those born moderately, very, and extremely preterm (Ruiz et al., 2018). In a study involving 3600 full-term and 1300 moderately, very, and extremely preterm children, parent-child dyads were observed at 9 and 24 months using home visits (Maupin & Fine, 2014). Researchers then coded parent behavior and found that parents of preterm children responded to their children's distress significantly less than parents of full-term children, even when controlling for overall child distress and gestational age at birth. Parents of extremely preterm 8-year-old children also tend to be more overindulgent, overprotective, and lack parental sensitivity compared to parents of full-term born children (Bilgin & Wolke, 2015; Faleschini et al., 2020; O'Mara & Johnston, 1989; Wightman et al., 2007).

1.4 Present Work

Despite the well-documented findings on the significance of the home numeracy environment and of the parenting differences for preterm children, it remains unclear how the home numeracy environment may be different for children born prematurely. In this study, I aim to examine the relations between preterm birth and parental number talk as well as parents' reports of the frequency of home math activities as two independent indices of the home numeracy environment (Bachman et al., 2020) (RQ1). In addition, I will also examine how birth status (preterm vs full-term) relates to children's counting skills (RQ2). For this investigation, I will measure parental number talk with their preterm and full-term toddlers during a semi-structured interaction and test children's counting skills directly. Additionally, I will investigate the differences in the home environments of preterm and full-term toddlers by analyzing survey results centering on what activities they engage in at home. I hypothesize that the parents of children born prematurely will use significantly less number talk and participate in fewer math activities than parents of full-term born children and that children born prematurely will also have lower counting skills.

2.0 Methods

2.1 Participants

A sample of 20 children (10 preterm and 10 full-term) and their parents participated in this study. Preterm children were 32 or fewer weeks gestational age with no minimum cutoff for gestational age (M = 31 weeks of gestation, SD = 1.155). Full-term children were born after 37 weeks of gestation. At the time of testing all children were between 24 and 36 months of chronological age. Preterm children and their parents were recruited from throughout the U.S. via social media postings as well as from a medium-sized U.S. city through a university participant registry, flyers in local libraries, museums, playgrounds, and other community settings, as well as through advertising at family-friendly events in the community. Informed written consent was obtained from all parents prior to the study. Data from full-term children and their parents were obtained from the Every Day Learning (EDL) study, a community-based study of 2-year-old children and their parents completed at the University of Pittsburgh, New York University, and the University of Maryland - College Park. A subset of dyads from the EDL study was matched to the sample of pre-term children based on the mother's age at the time of testing as well as the participating parent's and child's gender, parent's education, and parent performance on the parent math fluency measure (see description below) using propensity score matching. In this sample mother's age at the time of testing was used rather than the participating parent's age, as prior literature indicates that increased maternal age—independent of paternal age—is correlated with higher likelihood for premature birth (Stylianou-Riga et al., 2018). Additionally maternal age at birth has been shown to result in a variety of different parenting behaviors, once again independent of paternal age (Kalmijn & Kraaykamp, 2005; McCullough et al., 2017; Ragozin et al., 1982). Thus, maternal age was considered the more appropriate covariate.

Exclusionary criteria for preterm participants matched that of the preexisting EDL study. Children were excluded if the child was not between 24 and 36 months old, if the child had a cognitive, auditory, visual, or motor disability, or if the child was on the autism spectrum or had a significant speech delay. Additionally, children were excluded if both parents were not White and/or Hispanic/Latino, both biological parents were not involved in raising the child, the family did not have access to a computer or another device to use for Zoom calls, the family did not have reliable internet, or the family spoke languages other than English and Spanish at home. Additionally, all participating children must have been singleton births. All families received monetary compensation for their participation.

Descriptive statistics for the preterm and full-term sample can be seen in Table 1 and Table 2. To further characterize the preterm sample, a question was added to the questionnaire asking which, if any, early intervention services parents and their children participated in (Question 18 in Appendix A). Of the 10 children in the preterm group, 7 of them received early intervention services, with the majority of them receiving multiple types of interventions. The types of services received are outlined in Table 3.

Table 1. Descriptive Statistics of Sample After Propensity Scoring

Variable	Full-term	Preterm	Full Sample	P
	n	n	n	
Parent Gender				.639
Female	7	6	13	
Male	3	4	7	
Child Gender				1.000
Female	3	3	6	
Male	7	7	14	
Education				.531
University or Post Graduate Degree	8	9	17	
High School/Some College	2	1	3	

Table 2. Descriptive Statistics of Sample After Propensity Scoring

Variable	Full-Term		Preterm		P
	M	SD	M	SD	
Child's Age (in months)	32.347	3.637	30.690	3.963	0.343
Mom's Age (in years)	33.3	2.751	32.5	1.447	1.000
Math Fluency Score	24.9	8.66	24.6	9.823	0.943

Table 3. Intervention Services Participated in by Preterm Sample

Intervention Services	Preterm
	n
Speech Therapy	4
Physical Therapy	5
Occupational Therapy	2
Hearing Services	1
Nutrition Services	4
Family Training, Counseling, Parent Support Groups	2
Other	1

The study was introduced to parents as having the goal of understanding more about how children learn and think about the world around them by studying how interactions with parents foster children's cognitive development. All interactions with the parents and advertisements about the study avoided discussion of numeracy.

2.2 Procedure

All procedures and materials relevant for the current study were identical for preterm and full-term born children and their parents. However, participants in the EDL study completed additional child assessments and a second session for the purposes of the larger study. Data were collected in participants' homes through one Zoom call session lasting approximately half an hour and one Qualtrics questionnaire. All Zoom calls were video recorded to allow for later coding. The Zoom call session first consisted of a semi-structured parent-child interaction, after which children completed the counting task. Once the children completed the counting task, parents completed the Parent Math Fluency Assessment. Following the tasks, parents completed a Qualtrics questionnaire (Appendix A) which consisted of questions regarding basic demographic information, the child's vocabulary, the home environment (i.e., toys in the home and activities the parent and child engage in together), intervention services that the participating child has received, and the qualities parents hope to see in their children. The latter questions will only be used to characterize the sample and for exploratory purposes beyond the scope of the current study.

2.3 Measures

2.3.1 Parental Number Talk

To measure parental number talk while engaging with their children in a semi-structured interaction activity, dyads viewed and discussed two different images that the experimenter shared on the computer screen. Each dyad saw one indoor image (either of a kitchen or living room scene) and one outdoor image (either a barnyard or jungle scene) (see Figure 1). The order in which these images were shown as well as the specific images was counterbalanced across participants. Parents were instructed to discuss the images with their children as if they were pictures in a book and were told they can discuss the images for as long as they see fit. The researcher moved on to the next image when instructed by the dyad. To avoid bias, the parents were not informed that the purpose of this study was to examine parental number talk.

All interactions were recorded, and the dialogue was transcribed verbatim in Datavyu at the utterance level. Utterances were defined as any unit of speech separated by either grammatical closure or prolonged pausing (Bachman et al., 2020). These transcriptions were used to code the parents' number talk during the interaction. In line with prior work (Elliott, Braham, & Libertus, 2017; Silver, Elliott, & Libertus, 2021), utterances containing parental use of number words such as numerical uses of the word "one" and words that might elicit number talk (e.g., "how many," "number," "count") were tallied. Utterances in which numerical words were used in a non-numeric sense were excluded (e.g., "Pass me the blue one"). The total number of utterances spoken by the parent was also calculated to derive the proportion of talk that was about number concepts.

Figure 1. Parent-Child Picture Description Task Images

Barnyard Image

Living Room Image

Jungle Image

Kitchen Image

2.3.2 Child Counting Ability

Each child participated in a verbal counting activity. The experimenter shared their screen, and the child was first shown a white slide with an image of a bear. The child was then instructed to count the bears on the screen. The experimenter advanced the slide, adding one bear at a time, as the child counted. The task was completed when the child made his or her first error or if the child stopped and maintained that he or she cannot count higher. Up to 20 bears could appear on the slide for the children to count. Children's counting score was the highest number to which they correctly counted.

2.3.3 Parent Math Fluency Assessment

The participating parent completed a verbal math fluency assessment. The experimenter shared their screen, and the parent was shown a series of simple arithmetic problems (e.g., 3+4, 2x5). The parent was then instructed to solve the problems as quickly and as accurately as possible and share their responses verbally. The experimenter advanced the slides, showing new problems until 90 seconds were reached. Participants were allowed to skip items and move on to new problems if they could not think of the answer. For dual language users, the parent was given credit for correct answers in English or Spanish. Parents could solve up to 160 problems, but none of the parents reached the maximum number of problems. Parents’ scores on this assessment were used as part of the propensity score matching.

2.3.4 Home Learning Environment

As part of the Qualtrics questionnaire, parents were asked to report how frequently they engaged in listed activities with their child over the past month (Question 15 in Appendix A). The listed activities included 7 math activities (e.g., counting objects, using number activity books, playing board games with numbers) whereas the other 12 activities were more general academic activities (e.g., identifying the names of written alphabet letters, coloring, reciting nursery rhymes (such as "Mother Goose") or reading other rhyming books). The frequency of participation in each activity was assigned a point value ranging from “Did not occur” receiving one point to “Almost daily” receiving five points. To measure the home numeracy environment, parents’ responses across the 7 math activities were averaged. This survey of math activities showed high internal consistency, with Cronbach’s alpha of .79 for the preterm sample and .81 for the full-term sample.

2.4 Data Analysis

To address whether preterm born children experience different frequencies of opportunities for math learning compared to full-term born children, I conducted three separate analyses with two different indices of parental number talk and the frequency of home math activities as the dependent variables: the first model used number talk measured as the raw frequency of number words, the second model used number talk measured as the proportion of number words out of total talk, and the third model used the frequency of home math activities as reported on the parent survey. To test the specificity of any differences in number talk and home math activities, I also compared parents’ total number of utterances for the two groups as well as whether the frequency of home math activities was different by group controlling for the frequency of other learning activities. Due to the small sample, I repeated each analysis parametrically (two-sample t-test) and non-parametrically (Mann-Whitney U test). To address whether preterm and full-term born children differ in their counting skills, I again conducted a two-sample t-test, but this time predicting children’s counting skills from birth status.

3.0 Results

3.1 Assessment of Normality

Since we had a small sample size, determining the distributions of parental number talk, frequency of math activities, and total utterances was important for choosing an appropriate statistical method. To assess this a Shapiro-Francia test was performed and showed that the distribution of all variables did not depart significantly from normality: parental number talk (W' = 0.930, p = 0.137), frequency of math activities (W' = 0.97, p = 0.753), and total utterances (W' = 0.954, p = 0.14). Based on this outcome, parametric tests will be used as the primary analysis; nonparametric tests will also be included in the inferential analysis to ensure statistical validity.

3.2 Propensity Score Matching

Propensity score matching was used to select the subset of dyads from the full EDL study to be matched to the sample of pre-term children; therefore, controlling for potential covariates. The matching criteria included the participating parent’s gender, the child’s gender, the participating parent’s education level, the mother’s age at the time of testing, and the parent’s performance on the parental math fluency measure. Propensity score matching was conducted using matchIt in R, with nearest neighbor matching and no replacement(Ho et al., 2011). Table 1 shows the descriptive statistics for the two matched samples of the potential confounds that were categorical variables. To ensure there were no significant differences in the two samples, each potential confound was analyzed using a chi-square test of independence. There were no significant differences found in these two samples.

Table 2 shows the descriptive statistics for the two matched samples of the potential confounds that were continuous variables. To ensure there were no significant differences in the two samples, each potential confound was analyzed using a two-sample t-test. There were no significant differences found in these two samples.

3.3 Analysis of Home Numeracy Environment (RQ1)

3.3.1 Parental Number Talk

To address the first research question, I first examined number talk as a raw count. Descriptively, parents of children born full-term (*M* = 8.5, *SD* = 9.10) produced less number talk than parents of children born preterm (*M* = 12.2, *SD* = 10.91). To test this relation inferentially I first conducted a parametric two-sample t-test with parental number talk as the dependent variable and birth status (preterm or full-term) as the independent variable. As can be seen in Table 5, this relation was marginally significant ($p = 0.07$). Then, I conducted a Mann-Whitney U test to examine if this relation held up when tested nonparametrically. As demonstrated in Table 6, this relation remained marginally significant ($p = 0.102$).

Second, I examined number talk as a proportion of total utterances throughout the session. Descriptively, parents of children born full-term (*M* = 0.05, *SD* = 0.06) also produced less number talk as a proportion of their total talk than parents of children born preterm (*M* = 0.16, *SD* = 0.14). To test this relation inferentially I conducted a parametric two-sample t-test with parental number talk as a proportion of total utterances as the dependent variable and birth status (preterm or full-term) as the independent variable. As can be seen in Table 5, this relation was statistically significant ($p = 0.03$). Then, I conducted a Mann-Whitney U test and, as demonstrated in Table 6, this relation was marginally significant ($p = 0.079$).

To test the robustness of this effect, I ran another two-sample t-test with total parental utterances as the dependent variable and birth status (pre-term or full-term) as the independent variable. As can be seen in Table 5, this relation was not statistically significant ($p = 0.365$). Similarly, a Mann-Whitney U test confirmed that this relation was not significant ($p = 0.385$; Table 6).

3.3.2 Frequency of Math Activities

Descriptive statistics regarding the frequency of home activities as answered in Question 18 Appendix A, can be found in Table 4. On average, parents of children born full-term reported more home math activities (*M* = 2.98, *SD* = 0.64) than parents of pre-term born children (*M* = 2.10, *SD* = 0.68). This would translate to on average full-term children participating in math activities about once a week, whereas on average preterm children participating in math activities a few times a month. To test this relation inferentially I conducted a parametric two-sample t-test with home math activities as the dependent variable and birth status (preterm or full-term) as the independent variable. As can be seen in Table 5, this relation was statistically significant ($p = 0.008$). A Mann-Whitney U test confirmed that this relation was significant ($p = 0.010$; Table 6). To test the robustness of this effect, I ran an ANCOVA analysis controlling for child age and parents' frequency of engaging in general learning activities. Importantly, the main effect of birth status remained significant ($p = 0.004$) even with these controls.

Table 4. Descriptive Statistics of Home Math Activities by Birth Status

Activity	Activity Type	Full-Term		Preterm	
		M	SD	M	SD
Counting Objects	Math	4	1	1.8	2.30
Sorting things by size, color, or shape	General Learning	3.25	1.04	1.8	4.60
Counting down	Math	2.38	1.06	0.5	1.41
Identifying names of written numbers	Math	3.13	1.73	1.3	3.58
Buttoning buttons	General Learning	1.5	1.07	0.2	0.89
Putting Pegs in a board or shapes into holes	General Learning	1.78	0.83	0.5	1.41
Identifying names of written alphabet letters	General Learning	2.25	0.71	2.0	5.83
Building with blocks or construction set	General Learning	2.63	1.30	2.3	3.85
Using number activity books	Math	1.25	0.46	0.5	2.24
Playing board games with numbers	Math	1.29	0.49	2.0	1.79
Reading books that teach simple shapes like squares, circles, and triangles	Math	3.5	1.07	1.0	6

Scale: Did not occur (1); A few times a month (2); About once a week (3); A few times a week (4); Almost daily (5)

3.4 Analysis of Birth Status on Counting Skills (RQ2)

Counting skills were first descriptively analyzed for the full-term sample (*M* = 6.1, *SD* = 5.02) and the preterm sample (*M* = 4.4, *SD* = 6.33). To analyze the relation between birth status and counting skills, I performed a two-sample t-test which demonstrated there was no significant difference in counting skills between the full-term and preterm sample (p = 0.514). However, after performing the test nonparametrically there was a marginally significant result (p = 0.099) with children born full-term counting higher than children born preterm.

Table 5. Parametric Analysis of Children's Home Numeracy Environment and Counting Skills

Measure	Full-Term		Preterm		*t/F*	*p*
	M	SD	M	SD		
Parental Number Utterance (raw number)	4.8	5.029	12.2	10.912	-1.95	0.067†
Parent Number of Utterances (proportion of total utterances)	0.0476	0.055	0.159	0.139	-2.36	0.030*
Frequency of Math Activities	2.982	0.638	2.098	0.677	3.00	0.008**
Frequency of Math Activities					11.54	0.004**
Child's Age (in months)					2.08	0.168
Frequency of Literacy Activities	3.475	0.946	3.533	1.088	1.56	0.229
Child's Counting Skills	6.1	5.021	4.4	6.328	0.67	0.514
Total Parental Utterances	98.1	15.389	76	18.10	0.93	0.365

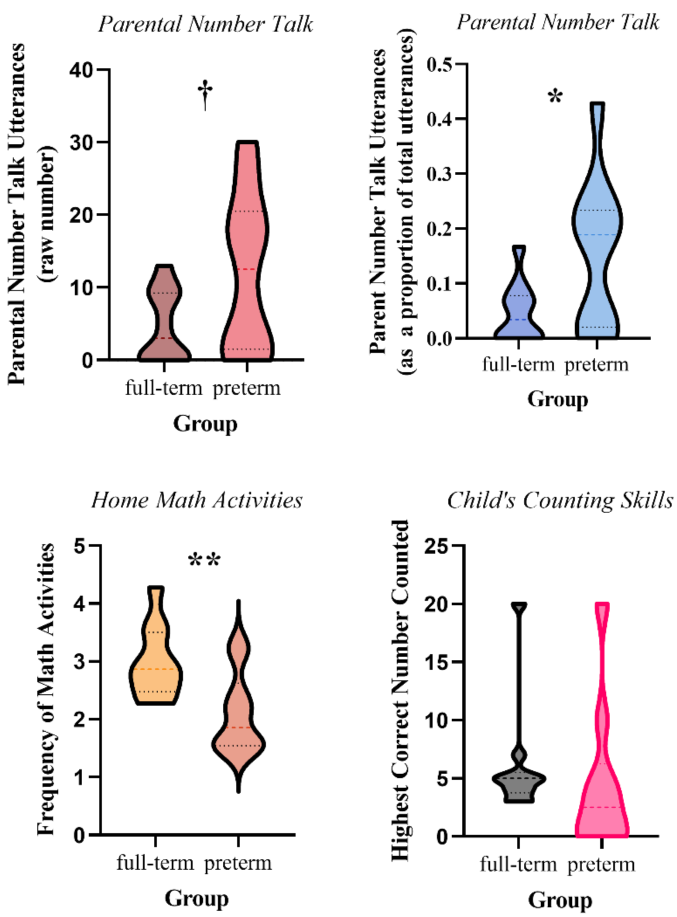
†p<0.1 *p<0.05 **p<0.01

Table 6. Nonparametric Analysis of Children's Home Numeracy Environment and Counting Skills

Measure	Full-Term		Preterm		*U*	*P*
	M	SD	M	SD		
Parental Number Utterance (raw number)	4.8	5.029	12.2	10.912	-1.53	0.102†
Parent Number of Utterances (proportion of total utterances)	0.0476	0.055	0.159	0.139	-1.75	0.079†
Frequency of Math Activities	2.982	0.638	2.098	0.677	2.58	0.010*
Child's Counting Skills	6.1	5.021	4.4	6.328	1.650	0.099†
Total Parental Utterances	98.1	15.39	76	18.10	0.870	0.385

†p<0.1 *p<0.05 **p<0.01

Figure 2. Children's Home Numeracy Environment and Counting Skills by Birth Status



†p<0.1. *p<.05. **p<.01

p-values represented are based on parametric statistics

4.0 Discussion

This study investigated differences in the home numeracy environment based on birth status (full-term vs preterm birth) and, furthermore, tested the relation between birth status and counting skills. We found that parental number talk was marginally significantly related to birth status when treated as a raw number and was significantly related to birth status once controlling for total talk or treated as a proportion of total talk. Unexpectedly, we found that children of full-term birth received significantly less number talk than children born preterm. Importantly, the two groups did not differ in the total amount of parental utterances suggesting that this effect is specific to number talk and not how much parents talk overall. However, we found that children born full-term participated in significantly more math activities at home according to parent reports. Counter to expectations, preterm and full-term born children did not differ in their counting skills. These findings suggest that there may be a fundamental difference between parental number talk and the types of math activities parents engage in with their children at home. Despite these different ways of engaging in math, we found no difference in math skills between the preterm and full-term samples.

4.1.1 Birth Status and Home Numeracy Environment

The first aim of this study was to assess whether there is a significant difference in parental number talk between parents of full-term and parents of preterm-born children. Our original hypothesis that parents of preterm children would use less number talk than parents of full-term children was not supported; in fact, there was statistically significant evidence of the opposite, at least when tested parametrically and number talk was measured as the proportion of number talk out of parents' total utterances. In initially forming our hypotheses we reasoned that due to parents of preterm children having far more of a requirement to focus on their child's immediate medical needs, intentionally engaging in parental number talk would be less of a priority when compared to parents of full-term children. These hypotheses were based on prior disability identity literature which explains that parental units tend to focus on supporting initial medical needs above all (Forber-Pratt et al., 2017; Gabel et al., 2016). As preterm birth is associated with health concerns and complications which are often associated with high financial and time demands especially at these early developmental milestones (Poehlmann-Tynan et al., 2015), we predicted that these prior findings would apply to our sample. However, this does not seem to be the case for parents of preterm children. Instead, it seems as though parents of preterm children are actively supporting math engagement, in the form of parental number talk, an action that goes well-beyond fundamental support of needs. One possible explanation for our results is that parents view preterm birth as fundamentally different than disability, despite the similar time demands, and are therefore, prioritizing math engagement and learning in a way that may be different than children with disabilities. One explanation for our result of higher number talk is that parents of preterm children, at least in this study, are capitalizing on the fact that number talk can easily be incorporated into everyday activities and providing their children with number engagement in this easily adaptable way.

In addition to assessing parental number talk, our study aimed to determine if there is a significant difference in the engagement in home math activities between parents with full-term and parents with preterm-born children. Our original hypothesis was that parents of preterm children would report engaging in home math activities less frequently than parents of full-term children, which was once again based on prior disability identity literature (Forber-Pratt et al., 2017; Gabel et al., 2016). One possible explanation for these findings is that there are often more health concerns and complications associated with preterm birth, especially during the early stages of development (Poehlmann-Tynan et al., 2015). As a result, parents of preterm children—especially parents of very preterm toddlers—may simply have less time to engage in formal math activities, than parents of full-term children. However, on average parents of pre-term children reported playing number board games a few times a month, similar to, if not more frequent than parents of full-term children. Arguably, playing number board games is a time-consuming activity that also requires dedicated time. Thus, more work is needed to fully understand why parents of pre-term children report engaging in less math activities.

The opposition of the two above findings is particularly interesting, as one would assume that they would align so that parents who engage in more number talk also reported higher engagement in math activities. The fact that our findings are in opposite directions suggests that parental number talk and the frequency of math activities are reflective of different aspects of the home numeracy environment. Although these findings were unexpected, it is not particularly surprising as several recent studies have demonstrated that parental math talk and reports of math activities in the home are not correlated with each other (Bachman et al., 2020; Miller et al., 2023). One potential explanation is that parental number talk may be indicative of parental numeracy support that is occurring during everyday situations, whereas the reported math activities may be more indicative of deliberate math learning opportunities at home. Additionally, it may also be possible that the parental number talk measurements in the current study are reflective of best-case scenario conversations (i.e., times in which parents and children sit down to formally interact without any interruptions or distractions), whereas the home numeracy activities measure may be more reflective of what families actually engage in. Additional work is needed to firmly understand the differences between these two measures.

In initially hypothesizing the direction of these findings, we reasoned that because parents of preterm children have many auxiliary demands, participating in math activities and number talk would likely be far less of a priority. While our hypotheses were not all supported, this reasoning may be a potential factor that contributes to the opposing directions of these findings. Namely, because incorporating number talk into everyday conversation is less demanding in effort and time than engaging in math activities, it is easier for parents who have more demanding priorities (e.g., the medical concerns many parents of preterm children face) to put more of their time and attention into talking about numbers during the course of their everyday activities, rather than engaging in explicit math activities at home.

In addition to having higher parental number talk and lower engagement in home math activities, the preterm sample interestingly also had far higher variability when compared to the full-term sample. This may be due to the variability in how parents of preterm children view and treat their children. One possible explanation for this is that perhaps some parents view their children as having a disability—therefore taking on a focus on needs mindset—while some parents may view their children as being developmentally equal to full-term children, and therefore treat them no differently. This may be especially prevalent as better medical technology that ensures the survival of children born preterm (Purisch & Gyamfi-Bannerman, 2017), making preterm birth more of a norm in our society.

4.1.2 . Birth Status and Counting Skills

Although full-term and pre-term born children seem to be afforded different amounts of math learning opportunities with their parents, we found limited evidence for differences in children's counting skills. Our findings may indicate that regardless of the type of math engagement, math-related input at home ensures the resilience of early counting skills. However, these results are counter to the well-documented differences in math skills between preterm children and their full-term born peers (Libertus et al., 2017; Schneider et al., 2004; Simms et al., 2013; World Health Organization, 1970). It is possible that these discrepancies are due to our much smaller sample size, the younger age of our participants, and/or the fact that we only tested children's counting skills using one task. Future studies should replicate our findings with a larger sample and more varied math assessments.

4.1.3 Limitations, Future Directions, and Conclusions

This study aimed to understand the relation between pre-term and full-term birth status and counting skills by examining the home numeracy environment. Although this study contributes to the information gap on preterm children in numeracy, there are several limitations that warrant our discussion and several avenues for future exploration.

First, although the data passes the normality assumption, the sample size is extremely small making the justification of generalizing this study rather difficult. Importantly, the families who participated in this study were all white and were mainly highly educated, meaning that in looking at these assessments of the home numeracy environment, there are likely broader implications regarding the families' sociocultural context. It is unclear how these findings would extend to a more racially and socioeconomically diverse sample. It would be particularly interesting to see a sample with greater heterogeneity in parents' education levels as parents of higher education levels have been shown to engage in higher levels of number talk than parents of lower education levels during non-math-related activities (Thippana et al., 2020).

Furthermore, it is possible that the estimates of number talk were somewhat biased by the structure of the picture description task. Our efforts in avoiding any discussion of math prior to the participation in the interaction tasks somewhat alleviates this concern; however, it is always possible that parents performed differently than they would have naturally knowing that they were recorded. Additionally, there is the potential for bias due to the reliance of parents' self-report of math activities (Elliott & Bachman, 2018), as they are not a direct observation of math activity frequency. Therefore, there is opportunity for future work that uses naturalistic observations to provide a more accurate picture of the home numeracy environment.

One strength of this study is the large participation of fathers. Fathers are notoriously underrepresented in developmental psychology research as it is more likely for mothers to be the primary caregiver of the child (Davison et al., 2017). Future research should investigate if there is a difference in the role of fathers and mothers in raising preterm children and how this may be different than for full-term children.

As medical technology advances, survival of preterm birth has become far more likely (Purisch & Gyamfi-Bannerman, 2017). This means that our current understanding of parenting preterm children may be outdated as this becomes more of a norm in our society. With such high variability within the preterm population, it is very possible that perceived differences between preterm and full-term children are making more of a difference in the quantity and type of math engagement they are receiving from parents, than biological differences. Future investigation is necessary to understand how parents of preterm children perceive their children and if that is different from full-term children. More broadly, larger queries should explore whether variations in brain maturation or parenting practices may explain differences in math abilities in preterm and full-term children.

The current study expands our understanding of how preterm birth is related to math skills and what environmental factors may contribute to their development. We found that children born full-term received significantly less number talk than children born preterm, while children born full-term participated in significantly more math activities at home according to parent reports than children born preterm. Additionally, we found no significant difference in math skills between the preterm and full-term samples. Overall, the results from the current study reveal a lot of exciting directions for future research, which can hopefully help researchers in this field better understand how children born preterm experience math learning and how to best support their math development.

Appendix A. Qualtrics Questionnaire

Q1 Participant ID

Q2 What is your race and ethnicity? Please select all that apply.

American Indian or Alaska Native (1)

Asian (2)

Black or African American (3)

Native Hawaiian or Other Pacific Islander (4)

White (5)

Hispanic or Latino (6)

Other -- please specify in the text box below (7)

Questions About Home

Q3 Are you the child's mother or father?

- Mother (1)
- Father (2)

Q4 What is your age in years?

Q5 What is the date of birth of the participating child?

____

Q6 What is the gender of the participating child?

○ Male (1)

○ Female (2)

Q7 What language(s) does the participating child speak? Please select all that apply.

▢ English (1)

▢ Spanish (2)

▢ Other -- please specify in the text box below (3)
____

Q8 What is the age of the child's biological mother?

____

Questions About the Child

Q9 After how many weeks and days of pregnancy was the participating child born?

_______________weeks

_______________days

Q10 What was the participating child's birth weight?

______________lbs

______________oz

Q11 Has the participating child experienced any ongoing health or developmental problems?

○ Yes (4)

○ No (5)

Q12 What health or developmental problems has the participating child experienced?

____

Q13 Has the participating child experienced any health or developmental problems during or after birth that no longer affect your child?

○ Yes (4)

○ No (5)

Q14 What health or developmental problems did the participating child experience?

____

Q15 In the past month, how often did you and your child do the following things at home (not at daycare or elsewhere)?

	Did not occur (1)	A few times in a month (2)	About once a week (3)	A few times in a week (4)	Almost daily (5)
Counting objects (1)	○	○	○	○	○
Sorting things by size, color, or shape (2)	○	○	○	○	○
Counting down (10, 9, 8, 7, …) (3)	○	○	○	○	○
Identifying names of written numbers (4)	○	○	○	○	○
Buttoning buttons (6)	○	○	○	○	○
Movement songs (i.e., Itsy Bitsy Spider) (7)	○	○	○	○	○
Coloring, painting, writing (8)	○	○	○	○	○
Identifying names of written alphabet letters (9)	○	○	○	○	○
Identifying sounds of alphabet letters (10)	○	○	○	○	○
Making music (11)	○	○	○	○	○

Playing with number fridge magnets (12)	○	○	○	○	○
Putting pegs in a board or shapes into holes (13)	○	○	○	○	○
Playing with puzzles (14)	○	○	○	○	○
Building with blocks or construction set (Duplo, Megablocks, etc.) (15)	○	○	○	○	○
Playing with "Playdoh", dough, or clay (16)	○	○	○	○	○
Using number activity books (like connect-the-dots) (17)	○	○	○	○	○
Playing board games with numbers (18)	○	○	○	○	○
Reading books that teach simple shapes like squares, circles, and triangles (20)	○	○	○	○	○

Recite nursery rhymes (such as "Mother Goose") or read other rhyming books (21)	○	○	○	○	○

Q16 What is the highest degree/certificate you have completed?

____

Q17 Have you ever participated in parenting classes or programs such as Strong Start or Reach Out & Read, or center-based programs?

○ Yes (1)

○ No (2)

Page Break

Q18 Please select all of the following early intervention services that the participating child has received/participated in?

- ◯ Speech Therapy
- ◯ Physical Therapy
- ◯ Occupational Therapy
- ◯ Hearing Services
- ◯ Vision and audiology services
- ◯ Nutrition Services
- ◯ Nursing Services
- ◯ Family training, counseling, home visits, or parent support groups
- ◯ Social work or psychological services

Q19 In the last 12 months, what was the total income of all members of your household from all sources before taxes and other deductions? Please include the income from your job(s), as well as any other sources such as public assistance programs, rental income, interest, and dividends.

- ◯ Total income (4) ____
- ◯ I'd prefer not to answer (5)
- ◯ I don't know (6)

Display This Question:

If In the last 12 months, what was the total income of all members of your household from all source... = I don't know

Q20 If you are unable to provide a number, was it...

- ◯ $25,000 or less (1)
- ◯ More than $25,000 (2)
- ◯ I don't know (3)

Display This Question:

If you are unable to provide a number, was it... = $25,000 or less

Q21 Was it...

- ◯ $5,000 or less (1)
- ◯ $5,001 to $10,000 (2)
- ◯ $10,001 to $15,000 (3)
- ◯ $15,001 to $20,000 (4)
- ◯ $20,001 to $25,000 (5)

Display This Question:

If you are unable to provide a number, was it... = More than $25,000

Q22 Was it...

- $25,001 to $30,000 (1)
- $30,001 to $35,000 (2)
- $35,001 to $40,000 (3)
- $40,001 to $50,000 (4)
- $50,001 to $75,000 (5)
- $75,000 to $90,000 (6)
- $90,000 to $100,000 (7)
- $100,000 to $150,000 (8)
- $200,000 or more (9)

Q23 Your responses have been recorded. You will receive your gift card via email within 2 business days. Please provide your preferred email in the text box below.

____

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