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Number Talk and Math Performance

By

Jing Wang (Maggie)

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Faculty Advisor: Susan Levine
Preceptor: Natalie Dowling

Abstract

This study investigates the relationship between number talk within families and children's math performance. Drawing on a sample of 71 first-grade children from low-SES backgrounds, we analyzed the frequency and context of number talk between parents and children during structured interactions. We hypothesized that both parent and child-initiated number talk would positively correlate with children's math achievement. Our findings reveal a significant positive correlation between parent and child number talk, suggesting reciprocal influences. However, no direct relationship was found between number talk frequency and math performance. Interestingly, a significant interaction effect was observed: children who initiated more number talk and engaged more frequently in number-related conversations demonstrated higher math achievement. Additionally, we explored the impact of child math anxiety on number talk frequency but found no significant relationship. These results highlight the complexity of factors influencing early math development and suggest the importance of active engagement in numerical discussions for improving math outcomes in young children. Future research should consider more naturalistic settings to better capture parent-child interactions and their impact on mathematical development.

Introduction

A solid mathematical foundation is necessary for young children to succeed in school. According to Aunola et al (2004) children's early mathematical abilities predict both their mathematical growth and their performance on math exams in later elementary school and even high school (Duncan et al., 2007). Additionally, children's performance in college and future career opportunities can be influenced by their mathematical achievement (National Mathematics Advisory Panel, 2008). The recognition of the far-reaching consequences of mathematical abilities has led an increasing number of parents to focus on fostering and enhancing their children's mathematical development from an early age (Sarama et al., 2009). Given the increasing importance attributed to mathematical abilities, we aim to investigate the underlying factors contributing to individual differences in children's early math knowledge.

Early Math Learning

There is a sizable disparity in math proficiency even at the beginning of kindergarten, with some students starting school with noticeably more mathematical knowledge than others (Clements et al., 2007). In fact, studies show that children exhibit significant variation in their mathematical knowledge as early as age 4 (e.g. Dowker, 2008; Ginsburg & Russell, 1981; Klibanoff, Levine, Huttenlocher, Vasilyeva & Hedges, 2006; Starkey, Klein & Wakeley, 2004; West, Denton & Germino-Hausken, 2000). As children advance through the educational system, these disparities in math proficiency tend to endure, and according to some, even widen. Moreover, multiple studies show that early mathematical knowledge predicts later math achievement and learning in elementary school and beyond (Duncan et al., 2009; Jordan et al., 2009; Watts et al., 2014).

Socioeconomic Status Effect (SES)

The average mathematical knowledge gap between children from low-income backgrounds and their peers from middle- and upper-class backgrounds highlights the concern about the wide range of individual variation in children's mathematical knowledge across different socioeconomic backgrounds (Starkey, Klein, & Wakeley, 2004). In particular, four-year-olds from lower-income families typically lag behind their middle-income peers by at least seven months (REF). Interestingly, performance on nonverbal numerical tasks is similar for children from higher- and lower-income homes, suggesting that these disparities are not consistent across all numerical tasks. Jordan, Huttenlocher & Levine (1992, 1994) found that kindergarten and first grade children from low-income families performed significantly worse than chidlren from middle-income families on calculation problems presented as verbal number facts or story problems but performed comparably on the same problems presented as nonverbal problems. On tasks requiring written numerals, story issues, verbally stated numbers, and higher level arithmetic problems, however, differences occur (Dowker, 2005; Jordan, Huttenlocher, & Levine, 1992, 1994). In addition to highlighting the existence of disparities in arithmetic performance between socioeconomic backgrounds, Dowker's research emphasizes the complex nature of these differences, implying that they go beyond particular arithmetic tasks and encompass more general cognitive processes and problem-solving strategies. (Dowker, 2005).

Number Talk in Family

In addition to the SES effect, parents' support may also influence children's math knowledge. One theoretical perspective is the sociocultural framework first suggested by Lev Vygotsky and his followers. Based on this concept, cognitive development is inherently tied to social and cultural contexts. Therefore, in this study we are going to examine how children's early interactions with adults can influence early mathematical development. According to Vygotsky's sociocultural theory, children's cognitive development greatly benefits from their social interactions with adults (Gauvain, 2001; Rogoff, 1990; Vygotsky, 1978). Generally speaking, play and other spontaneous activities are often seen as particularly important situations in which adults provide information to children, assist in the development of children's skills, and deepen children's conceptual understanding. In other words, informal activities at home, such as meal preparation, grocery shopping, housework, and cooking, can expose kids to a lot of numerical information that helps them build their mathematical comprehension on a daily basis (Saxe, 2004; Walkerdine, 1988). For example, parents and children could count the number of tomatoes while buying groceries or estimate the time needed to boil an egg.

Children's early experiences at home are therefore one possible source of variance in numerical understanding. These experiences include being exposed to activities using numbers as well as the quantity and kind of language they encounter regarding numbers. These differences in the family setting may have an impact on how well kids learn numbers.

Current Study

The present study was designed to extend previous research and investigate the relationship between number talk and math performance. Previous studies focus only on number talk from parents or number talk from children. This study combines both. Our first hypothesis is that number talk from parents and number talk from children are both positively correlated with children's math performance. Our study aspires to provide a more comprehensive understanding of how these interactive number talk within the family environment collectively contribute to children's mathematical proficiency. The integration of parental and child use of number talk allows for a nuanced exploration of the reciprocal influences and dynamics during number talk, shedding light on potential synergies or discrepancies that may impact a child's overall math performance.

We also investigate potential differences in the initiation of number talk between children and parents. While previous research has predominantly focused on one or the other as initiators of these mathematical discussions within the family context, our study seeks to compare instances in which children initiate the conversation with instances in which parents take the lead. Therefore, our second hypothesis is that if children initiate more number talk, their math performance is better than those whose parents initiate more number talk. By examining these patterns, we aim to identify any unique dynamics associated with each initiator and understand how these interactions may influence children's engagement and proficiency in mathematics.

Lastly, building on the previously reported relation between parent math anxiety and child number talk (Berkowitz et al., 2021), we want to further explore the relationship between child math anxiety and child number talk. We predict higher child math anxiety predict less child number talk.

Method

Participants

Our participants are 71 first-grade children (35 boys and 36 girls) with a mean age of 96.58 months (range= 87 to 118 months, SD= 5.93 months) and their primary caregivers. Caregivers are mostly mothers but there are also 5 fathers and 2 extended family members who participated. The gender of the participants were equally distributed, with 35 boys and 36 girls. Among 71 participants, 55 were African American/Black, 2 were Asian/Asian American, 1 was American Indian/Alaskan Native, 1 was White non-Hispanic, 1 was Latino, and 11 were mixed/other race. The majority of families (N=68) spoke English at home. We recruited participants from another larger study, in which participants are all from low-SES families (80% of families with an income of <$50,000). Informed consents were obtained from the parents or legal guardians of the children, ensuring a thorough understanding of the study's purpose, procedures, and potential risks.

Procedure

At the end of frist grade, we collected children's math performance. The Woodcock-Johnson IV Tests of Achievement's Applied Problems subtest was used to measure math achievement in one-on-one sessions with an experimenter at the school (Schrank et al., 2014). Children's number correct on this test was converted to a W score, a Rasch-scaled score, which provides a valid metric for examining students' math performance (a score of 500 roughly corresponds to a 10-year-old's average performance).

Then, we collected data about children's math anxiety by using the Child Math Anxiety Questionnaire -Revised (CMAQ-R: Ramirez et al., 2016) . The CMAQ-R was designed to be particularly suitable for first- and second-grade students. It contains 16 items that ask children how nervous they would feel during different math-related situations. Children were asked to point to one of five smiley faces displaying an emotional gradient from not nervous at all (1) to very, very nervous (5) in a left to right format consistent with children's emotional magnitude estimations.

After that, children and parents participated in a task conducted through a Zoom session with a researcher. The task involved the presentation of three different images in a fixed order: a weeklong weather report , a train station, and a produce stand (Figure 1). The researcher provided minimal instructions to the dyad, encouraging them to discuss the image naturally, as they would at home. During the discussions, the researcher turned off the video, muted their camera, and left the room in order to encourage naturalistic interactions. The dyad's discussions for each image continued until the participants indicated they were finished or were stopped by the researcher after a maximum of 5 minutes. Consequently, the total maximum duration for the three images was 15 minutes. However, we only focused on the data from the produce stand for this study. We chose to examine discussions around this image because a previous study showed that this image involves most number talk (Zhang, Smithstein, & Levine, in prep).

Figure 1

Our aim was to collect qualitative and quantitative data about parent-child conversations. We therefore video recorded the entire session in order to code and analyze the data. First, every word said by the parent and child during the discussion was coded and entered into an Excel template. The parents and children’s speech were broken down into utterances, which were defined as speech phrases followed by a noticeable pause, a shift in the direction of the conversation, or an alteration in intonational pattern.

Utterances served as the unit of analysis for the coding process. Each utterance was coded according to two categories: number talk and other talk (non-number). Number talk refers to any utterance that includes numerical use of numbers, such as cardinal values and counting (e.g. “one, two, three”), as well as references to Arabic numerals (e.g. “The number one”) and to time or age (e.g. “one minute”, “when you turned one”). Non-number talk refers to utterances that do not include numbers or that include non-numerical use of numbers (numbers that do not represent a quantity). All other uses of numbers were coded as non-numerical (deictics, e.g. “which one”; anaphoric uses of one, e.g. “this is the expensive one”; and idioms, e.g. “one of these days”) (Eason, et al. 2021).

Lastly, we coded the number of times that children initiated the number talk. When children say a sentence that includes numerical use of numbers without a question asked or when they start a conversation that has the intention to involve numbers that was coded as child initiated number talk. For example, child initiation was coded for the child utterance "apples are $3.5 each or $1.75 per slice " (Parent didn't ask children the question)”, and “so how much money do we left?” When there is a transition from one question or statement to another, we identify that as the end point of a conversation. We then identify who the initiator of the next conversation is (Eason, et al. 2021). Two trained coders conducted the number talk and initiator coding. Approximately 25% of the transcripts were double-coded in order to assess inter-rater reliability. Where codes differed, the coders reached a consensus to determine the final code. Reliability was strong, with a Cohen’s kappa coefficient of 0.98 for parent number talk, 1.00 for child number talk, and 0.93 for child initiated.

Results

We first report descriptive data of the frequency of parents’ and children’s number talk. The average instances of parent number talk was 16.33 utterances (Range = 0 - 41; see Table 1). The average instances of child number talk was 13.23 utterances (Range = 0 - 34; see Table 1).

The average of child math anxiety was 42.62 (Range = 16 - 76; see Table 1). The average of child math achievement was 444.80 (Range = 415.00 - 485.00; see Table 1)

Table 1. Descriptive data (unit for talk type is in utterances)

	Parent		**Child**				
	Number Talk	**Other Talk**	**Number Talk**	**Other Talk**	**Initiate**	**Math Anxiety**	**Math Achievement**
Min.	0.00	8.00	0.00	5.00	0.00	16.00	415.00
Median	14.00	39.50	11.50	19.00	4.00	42.50	444.00
Mean	16.33	41.02	13.23	21.91	5.55	42.62	444.80
Max.	41.00	92.00	34.00	49.00	24.00	76.00	485.00

Hypothesis 1a: Relation between parent and child number talk

In order to investigate hypothesis 1, we used correlation analysis to assess the strength and direction of the relationship. Results show a positive correlation between child number talk and parent number talk, r (62) = .28, p =.01 (see Table 2). Additionally, there is no correlation between child number talk and parent other talk, r (62) = .16, p =.06, although this relation approached significance. Finally, there was no significant relation between child number talk and child other talk, r (62) = -0.11, p =.44 (see Table 2).

Hypothesis 1b: Relation between parent and child number and other talk and child math achievement

Results also shows there was no significant relationship between child math achievement and the frequency of parent and/or child number talk (see Table 3).

We then used a regression model to test the relations of parent number talk, = .06, t (61) = .36, p = .72, child number talk, β = .33, t (61) = 1.48, p = .15, parent other talk, β = -.12, t (61) = -.8, p = .42, and child other talk, β = .04, t (61) = .16, p = .88(see Table 4). The results revealed that none of them was a significant predictor of child math achievement.

Table 2. Correlations of child number talk and parent number talk

	Estimate	Standard Error	t value	Pr (>| t |)
Parent Number Talk	.28	.09	3.18	.01
Parent Other Talk	.16	.08	1.88	.06
Child Other Talk	-0.11	.14	-0.78	.44

Table 3. Correlations among parent number talk, child number talk, and child math achievement

	Child Math Achievement	Parent Number Talk	Child Number Talk
Child Math Achievement	1.00	.12	.11
Parent Number Talk	.12	1.00	.53
Child Number Talk	.11	.53	1.00

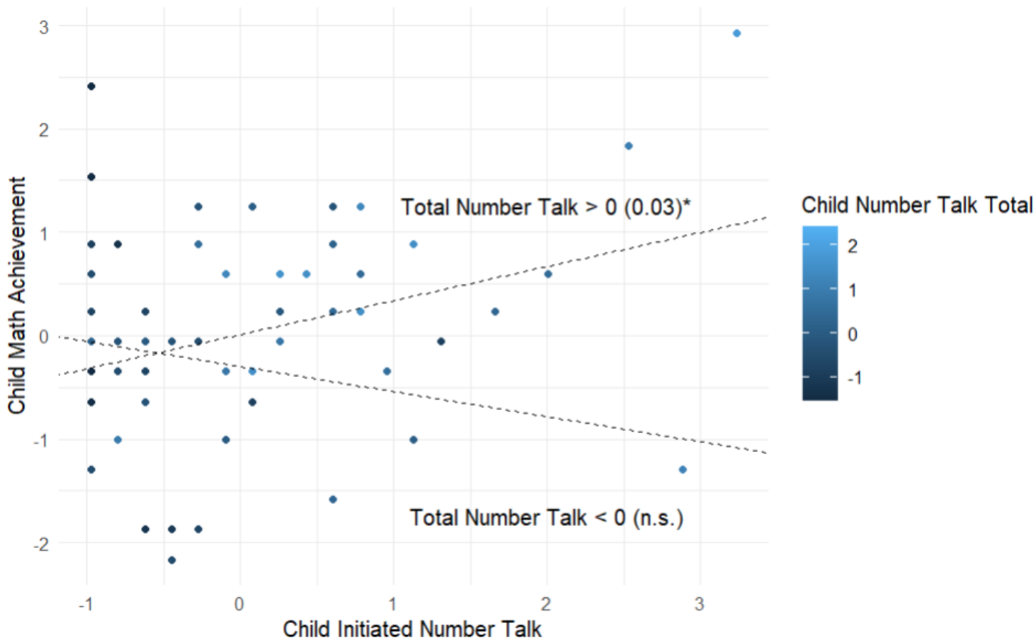
Table 4. Regression model predicting child math achievement

	β Estimate	Standard Error	t value	Pr(> | t |)
Parent Number Talk	.06	.17	.36	.72
Child Number Talk	.33	.22	1.48	.15

	β Estimate	Standard Error	t value	Pr(> | t |)
Parent Other Talk	-.12	.15	-.8	.42
Child Other Talk	.04	.25	.16	.88

Hypothesis 2: Relation of child initiated conversations and children's math performance

A regression model revealed that child-initiated conversations, $\beta = -1.18$, $t\ (62) = -1.59$ $p = .12$, and child number talk, $\beta = -.29$, $t\ (61) = -1.03$, $p = .31$, did not significantly predict child math performance. However, there was a significant interaction effect between child-initiated conversations and child number talk, $\beta = .09$, $t\ (61) = 2.55$, $p = .01$ (see Table 5), which indicates that the relation of child-initiated conversations on math performance is moderated by the frequency of child number talk. We plotted two lines (see Graph 1), one using data where the child number talk was above the mean (so greater than 0) and one using the data where the child number talk was below the mean (so less than 0). For children who initiate number talk and speak about number more than average, that is positively related to their math achievement. But, for children who initiate number talk and speak about number less than average, it is slightly negatively related to their math achievement, but that isn't significant.



Graph 1

Table 5. Regression model predicting child math performance from the interaction of child initiated and child number talk

	Estimate	Standard Error	t value	Pr(> | t |)
Child Initiated	-1.18	.74	-1.59	.12
Child Number Talk	-.29	.28	-1.03	.31
Child Initiated X Child Number Talk	.09	.03	2.55	.01

Hypothesis 3: Child math anxiety negatively related to child number talk

To investigate hypothesis 3, we used a linear regression model to estimate the relationship between child math anxiety and child number talk. The results revealed that child math anxiety was not a significant predictor of the raw total math talk, $\beta = .05$ $t(64) = 0.58$, $p = 0.56$ (see Table 6). This suggests that variations in child math anxiety levels were not associated with observable differences in the frequency of number talk initiated by children during parent-child interactions.

Table 6. Linear regression model predicting number talk from child math anxiety

	Estimated	**Standard Error**	**t value**	**Pr(> | t |)**
Child Math Anxiety	.05	.09	.58	.56

Discussion

The positive correlation between parent number talk and child number talk observed in our study highlight the relation between child and parent number talk. It could be that child number talk increases when parents use more number talk, that parent number talk increases when children use more number talk, that this relation is bidirectional, or that both parent and child number talk are related to another variable. This finding is consistent with previous research emphasizing the significance of parent-child interactions in fostering early mathematical development (Eason et al., 2021).

We also found that there is a positive correlation between child math performance and the combination of child-initiated number talk and child number talk, which emphasized that child initiated talk is a predictor of child math performance when children use relatively more number talk. Our findings suggest that when children actively engage in number talk and tend to initiate the number talk by themselves, their math performance is also higher.

However, the findings of this study failed to reveal a statistically significant relationship between number talk from parent and child and child math performance. Although the lack of significant results may seem disappointing, it does not necessarily indicate the absence of relationships. There might be several factors that are likely contributed to this insignificant result.

First of all, this study involved coding parent-child talk in a short 5 minute recording video with a scenario selected by researchers, which was not a real life setting. Although we asked participants to interact as naturally as they would at home, there are still differences as children normally won't sit in front of a computer and discuss a picture with their parents while being recorded. In other words, this study may fail to reflect children's real behavior at home. Future studies could refine the study methodology to better reflect real-life settings and therefore increase the validity. For example, researchers could ask parents to video record their interactions with their children during routine activities, such as grocery shopping, cooking, or setting the table. This approach would offer a better representation of parent-child interactions in naturalistic environments, allowing for a deeper understanding of how these interactions influence children's mathematical development.

Moreover, the wide range of utterances recorded during the parent-child interactions, spanning from 11 to 105 for parents and 10 to 67 for children, which suggests potential variations in participant engagement. Participants who contributed minimally, with only 10 or 11 utterances, may not have fully embraced the study tasks or didn't take the study seriously, which might compromise data quality. Future studies could use a reward system to encourage children to actively participate in the study and therefore collect more useful and meaningful data. Additionally, researchers could ask children to take the lead in the conversations to provide more information about child initiated number talk and how parents respond to this.

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