Not All Math Support is Created Equal: Exploring Associations Between Parental Math Language Styles and Preschool Children's Math Talk and Math Skills

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Prior work on parental math support and preschool children's math performance has taken a variable-centered approach by capturing frequencies of different types of math language (i.e., questions, statements, and confirmations) and associating these frequencies with children's math talk and skills. The present study instead utilized a person-centered approach to explore the presence of parental math language styles and associations between these styles and children's math talk and math skills. Participants were 76 mostly middle-income, White parents and their four-year-old children (*M* age = 53.32 months; 45% girls). Dyads were videotaped sharing a picture and their utterances were transcribed and coded for math content. Children's math skills were assessed using the Preschool Early Numeracy Scale (PENS) and the Early Patterning Assessment. Using cluster analyses, three parental math language styles were identified: Math Discussers, who used a combination of math language types, Math Commentators, who used mostly math statements, and Math Elicitors, who used mostly math questions. Math Discussers were more likely than Math Commentators to have children who spoke more about math and there were no differences between styles in children's math skills. Findings suggest that parental math language styles provide a unique explanation for children's math talk.

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1.0 Introduction

Children begin kindergarten with wide variability in their math skills, skills which predict later achievement in elementary school and beyond (Jordan et al., 2009; Rittle-Johnson et al., 2017). This variability may be explained by, among other factors, parental math language and support in the home environment. Several observational studies have found positive associations between the frequency and type of parental math language and preschool children's math talk (Eason et al., 2021; Zippert, Daubert, et al., 2019) and math skills (Ramani et al., 2015; Susperreguy & Davis-Kean, 2016; Vandermaas-Peeler et al., 2012). Notably, all these studies have adopted a variable-centered approach to examining parental math language. A variable-centered approach entails focusing on the frequency of parental questions (e.g., how many frogs are there?), statements (e.g., there are more cups than plates), and confirmations (e.g., that's a six, after the child points out a six) that involve math during conversations with their children.

In this study, I use a person-centered approach to identify *styles* of parental math language and examine associations between these styles and children's math talk and their performance on math assessments. A person-centered approach entails looking at the way parents combine questions, statements, and confirmations into a style or pattern of support, an approach that has been taken in the literature on language and literacy development but not in math (Caspe, 2009; Wei et al., 2019). For example, while one parent can adopt a style characterized by providing many statements and using few questions and confirmations, another parent can adopt a style characterized by a similar number of questions, statements, and confirmations.

Given that a person-centered approach is relatively novel in the field of math development, I compared parental math language (i.e., parental utterances with math content) using a person-centered approach vs. a variable-centered approach to understand which approach better explains preschool children's math talk and math skills. In addition, I also compared parental general language (i.e., parental utterances with no math content) using a person-centered approach vs. a parental math language person-centered approach to further understand whether relations found were domain-specific or not.

1.1 Theoretical Framework

This study takes an ecological systems model and a cognitive input approach to studying parental math support. From an ecological systems model perspective, parents serve as one set of proximal influences that play a major role in their children's learning and development (Bronfenbrenner, 1979). This model highlights how different systems influence one another, such as the effects of parents' and children's external environments on the way parents and children interact with one another. From a cognitive input theory perspective, parents' frequency of engagement around learning activities with their child is associated with children's learning (Morrison et al., 2005). Time spent on these activities between parents and children is critical for children's development, especially prior to the start of school. Cognitive input theory also posits that language input is related to children's learning. Early adult-child engagement around math language is strongly related to children's math knowledge (Ginsburg et al., 2008). In addition, children's exposure to math activities is strongly positively related to their math skills (Bachman et al., 2018; Elliott et al., 2017). This theory demonstrates the importance of developing language to express the mathematical concepts children are learning to support children's math development.

1.2 Measuring Children's Math Talk and Skills

1.2.1 Math Talk

Before children learn how to solve math problems themselves, they learn how to talk about math. Parents and children engage in conversations about math in a variety of settings, including free play (Eason & Ramani, 2020), games (Zippert, Daubert, et al., 2019), and family food routines like grocery shopping and cooking (Hanner et al., 2019; Vandermaas-Peeler et al., 2012). Past literature examining children's math talk has found that children are capable of discussing many important concepts in early childhood including foundational topics such as counting and identifying numbers and more difficult concepts such as adding and subtracting (Daubert et al., 2018; Ramani et al., 2015). One study of mostly White parents with their 4- to 5-year-old children in the U.S. observed playing with a set of toy foods found that children used a variety of different words about fractions, quantity, and numbers (Eason & Ramani, 2020). Children also initiate conversations about math, as evidenced by results with mostly White mothers and their 4-year-old children observed playing with a set of post office-related toys in which children initiated close to one-fifth of all math interactions with their parent, often focusing on comparisons and quantity in the play materials (Vandermaas-Peeler et al., 2007). Additionally, children's math talk is related to their math skills. A recent review found strong positive associations between preschool children's math language knowledge and their math skills, demonstrating the ways in which children's math talk is related to their math skills (Turan & De Smedt, 2022). More specifically, 3- to 5-year-old mostly Black, low- to middle-income children's math talk was positively correlated with their performance on a measure of foundational number knowledge (Ramani et al., 2015). Additionally, in a sample of mostly White parents from a range of income levels and their children observed every four months from the time the child was 14 months to 30 months, children's cumulative experience talking about math across the timepoints predicted their math skills at 46 months (Levine et al., 2010). These results suggest the value in understanding relations to both children's math talk and their math skills.

1.2.2 Math Skills

There are several foundational math skills that are needed for preschool children to succeed in school (National Research Council, 2009; Purpura & Lonigan, 2015). Among the most studied by prior research are counting and cardinality, set comparison, number identification, adding and subtracting, and patterning. Counting and cardinality include understanding the one-to-one correspondence between numerals and quantities, the stable and ordinal nature of numbers when counting, and the expectation that the final number in a counting sequence represents the value of that set. Around age 4-5, children show large variability in their counting and cardinality abilities, which are positively associated with concurrent adding and subtracting skills (Dowker, 2008). Children's set comparison skills include their understanding of terms like "more", "less", "most", and "least," which enable them to compare visual sets. Set comparison skills in 3- to 5-year-olds are positively associated with other concurrent skills in numbering (i.e., counting and cardinality) and arithmetic (Purpura & Lonigan, 2013). Children's ability to recognize numerals (e.g., attach the verbal word "six" to the written number "6"), is also important in early childhood. Preschool children's number identification is strongly related to other important early numeracy skills like counting, cardinality, addition, and subtraction (Litkowski et al., 2020) and is positively related to overall math achievement in preschool (Chu et al., 2016). Developing adding and subtracting skills enables children to learn the rules that govern arithmetic and practice their problem-solving skills (Bisanz et al., 2005). Finally, by learning to detect patterns and determine what is missing from a pattern, children begin to understand rules and relations between objects. Preschool children are most successful with understanding repeating ABAB patterns and there are strong relations between children's performance on these tasks and their concurrent general math knowledge (Rittle-Johnson et al., 2019; Zippert, Clayback, et al., 2019).

Many of these math skills are also predictive of future academic success. Advanced counting skills, such as counting backward from a number, in preschool were the best predictor of fifth grade math achievement compared to other preschool math skills (Nguyen et al., 2016). Kindergarten children's set comparison skills were predictive of their arithmetic skills in first grade and fact retrieval in second grade (Desoete et al., 2012). Early number knowledge in preschool including children's number recognition is also positively associated with later arithmetic skills in first grade (Östergren & Träff, 2013). In addition, kindergarten adding and subtracting skills are predictive of math performance in third grade and gains in math achievement from first to third grade (Jordan et al., 2009). Patterning skills in preschool are also predictive of fifth grade math achievement (Nguyen et al., 2016; Rittle-Johnson et al., 2017). As a result, measuring children's early math skills using items related to counting and cardinality, set comparison, number identification, adding and subtracting, and patterning should capture children's understanding of foundational math concepts prior to the start of school.

1.3 Parental Math Support and Children's Math Talk and Skills

A growing number of studies have explored the ways that parents support their children's math development and how this support is associated with children's math talk and math skills (Hornburg et al., 2021). While some studies have used observational measures of parental math language, others have used parent-report survey measures of math activities at home (Bachman et al., 2020). One of the advantages of using observational measures is that it allows researchers to take a closer look at the specific parental behaviors that support children's math development. Prior observational studies have focused on parental math language, that is, the frequency with which parental speech directed at children contains math (Leyva, 2019; Susperreguy & Davis-Kean, 2016; Vandermaas-Peeler et al., 2012). Research on parental language often focuses on two key components: type and content (Leyva et al., 2011). The "type" refers to the specific kind of parental utterance (e.g., via questions, statements, or confirmations). The "content" refers to the use of math-related support, including the specific subdomain targeted (e.g., counting/cardinality, number identification, etc.). The type and content of parent language is often associated with the type and content of child language, suggesting that variation in one can be used to predict variation in the other (Leech et al., 2018). Regarding the **type** of parental math language, prior studies have focused on questions, statements, and confirmations.

1.3.1 Questions

Questions provide children with opportunities to apply concepts in different contexts, use their math vocabulary, demonstrate their learning, and be challenged to think in new ways (Duong et al., 2021). Studies have shown that the type of question parents pose might depend on children's math engagement and performance (Eason & Ramani, 2020; Uscianowski et al., 2020). One study examining parental math support within a sample of mostly White, mid- to high-income parents and their 4- and 5-year-old children in the U.S. demonstrated that parents engage in both closed-ended (e.g., is that equal?) and open-ended questions (e.g., how many pieces is that?) when talking about math, but they use more open-ended questions when children are more engaged in learning (Eason & Ramani, 2020). But not all questions are equally related to children's math skills. There were no associations between the frequency of questions that mostly White, mid- to high-income parents posed to their 4-year-old children during a structured play time and children's math skills (Duong et al., 2021). However, parents' frequency of high cognitive demand questions (e.g., comparing, predicting) were related to children's math skills compared to parents' frequency of low cognitive demand questions (e.g., labeling, matching). In addition, when mostly White parents from a range of economic backgrounds were asked to imagine what math questions they would pose to their 3- to 4-year-old child while reading a storybook, parents asked more complex questions about number when they reported their children had higher math abilities (Uscianowski et al., 2020). The research on parental math questions has tended to include samples with many White, middle-income parents to explore relations between parental questions and children's math abilities. These results indicate that, in this sample, just looking at frequency of questions does not fully explain children's math skills.

1.3.2 Statements

Statements make up another important parental language type, which are utterances through which parents provide new information, respond to children's questions, and vocalize observations about the task or activity (Son & Hur, 2020). When used appropriately, statements can be a valuable tool for parents to add to what their children know with their own knowledge and experiences (Levine et al., 2010). For example, while overall parent math talk was not related to children's math skills, mostly White parents from a range of economic backgrounds with preschoolers (age 4) who used a large amount of task-orienting talk (i.e., statements directing the child's attention on the task, such as narrating behaviors and explaining steps), had children with advanced math skills (Son & Hur, 2020). These results suggest that more specific support is more strongly related to children's math learning rather than general amount of math talk. Statements are also used as a tool to respond to children's questions, and low- to mid-income, White and Black parents of 4-year-olds vary in the amount of explanation and support they provide when answering children's questions (Kurkul & Corriveau, 2018). The research conducted on parental statements has utilized more diverse samples than studies conducted on parental questions, while still finding mixed results in relations to children's math skills. Few studies have made direct comparisons between parents' use of questions and statements. One study that coded parent-child math conversations during pretend play between mostly White, middle income parents and their 2- to 4-year-old children found that, while both parental math questions and statements were uniquely related to child math talk, only questions were associated with diversity of child math talk (Eason et al., 2021). Additionally, parental math questions were positively related to length of parent-child math talk compared to parental math statements.

1.3.3 Confirmations

Parents also support their children's math development through utterances that neither prompt children nor provide their own information, but instead maintain the flow of conversation. In math talk between middle class, mostly White parents and their 5-year-old children, parents use a range of techniques to maintain conversation, including affirming, disaffirming, or confirming the child's own utterances (Bjorklund et al., 2004). Although no published studies have yet to specifically investigate associations between parental confirmations and children's math skills, research in the field of children's language and literacy has explored these associations. A meta-analysis of maternal use of confirmations during parent-child conversations found that this parental language type was positively associated with children's memory skills (Wu & Jobson, 2019). These results suggest that parental confirmations may play an important role in facilitating conversations between parents and their children.

1.3.4 Content

Regarding the **content** of parental math talk, prior studies have explored associations between parental utterances about math (e.g., counting and cardinality, adding and subtracting) and children's math talk and skills. When mid- to high-income White parents asked more questions about counting with their 4-year-olds during a cooking activity, children had higher counting skills (Vandermaas-Peeler et al., 2012). Additionally, Black, low-income parents who talked more about advanced number skills (e.g., counting and cardinality) with their 3- to 5-year-olds during a play interaction had children with greater advanced numeracy skills (Ramani et al., 2015). Parents in this study who spoke more about math also had children who spoke more about math. In addition, low-income, mostly White parents' number talk with their 4-year-old children during a home cooking activity positively related to children's concurrent math skills, though overall parent math talk did not (Son & Hur, 2020).

Parental math talk is also predictive of children's future math skills. In Chile, low-income parents' math talk about counting, adding, and subtracting was positively related to gains in their 3- to 5-year-old children's math skills by the end of kindergarten (Leyva, 2019). Furthermore, when mostly White, mid- to high-income parents and their 4- and 5-year-old children in the U.S. were audio recorded in their homes during mealtimes, parental math talk positively related to children's performance one year later on an assessment of early mathematical abilities (Susperreguy & Davis-Kean, 2016). Use of two distinct samples to draw the same conclusions suggests that the relations between parental math language and children's math skills may be present in a variety of populations.

Taken together, prior literature suggests that both the **type** and the **content** of parental math language play an important role in children's math talk and math skills. Therefore, in this study, I will examine both aspects when identifying styles of parental math language.

1.4 Domain-Specificity

Early literacy and numeracy skills are strongly interconnected. One study with mostly White 3- to 5-year-olds from varying family incomes found that children's print knowledge and vocabulary skills were significant predictors of their numeracy skills a year later (Purpura et al., 2011). Children's language skills have also been found to mediate the relation between parent education and children's math skills (Slusser et al., 2019). Not only are children's math and language skills related, but parental support may be related to both children's math and language skills. Results of a study with a group of racially and economically diverse mothers in the U.S. demonstrated that mothers' distancing language, or the ways in which they encourage their child to relate current actions to past or future events, while sharing a wordless picture book with their 5-year-old child was positively associated to their children's math and language skills (Ribner et al., 2020). Together, these results suggest the value of also assessing whether relations between parental language and children's skills are particular to one domain (math) or extend to other domains (language). Hence, I examine whether parental math language relates to children's language skills as well.

1.5 Parental Support Styles

There is huge variability in both the type and content of parents' math talk with their children (Schnieders & Schuh, 2022). Because of this variability, there is value in recognizing that the relation between parental language and children's talk and skills is likely more than just looking at the frequency of different parent behaviors. By adopting a person-centered approach and identifying styles of parental math language rather than using a variable-centered approach and focusing on frequencies of parental math language types, it is possible to provide a complementary and novel perspective to understand parental influences on children's math development. From a methodological perspective, taking a person-centered approach enables researchers to consider the ways that parents combine different parental language types like questions, statements, and confirmations and how these styles might relate to preschool children's emerging skills (Haden et al., 1996). This approach of exploring combinations of parental language types has not yet been investigated in the math development literature, though evidence from studies on literacy and language development suggests that these styles are related to children's talk and skills (Caspe, 2009; Melzi et al., 2011). From a theoretical perspective, identifying parental styles can capture other forms of support that have not been identified by prior literature. Children do not just experience one type of math language, so by adopting a person-centered approach, it is possible to explore how parents combine different language types together to encourage children's learning.

Several studies on language and literacy development have adopted a person-centered approach to examine parental language during book-sharing or conversations about past events (i.e., reminiscing) with their preschoolers, have identified specific parental styles, and have found positive associations between such styles and children's talk and language and literacy skills (Caspe, 2009; Haden et al., 1996; Melzi et al., 2011; Wei et al., 2019).

One study focused on the type of parent utterance (whether parents asked questions, made statements, and provided confirmations) during reminiscing with their preschoolers (Melzi et al., 2011). The study identified two styles: the *Constructor* and the *Elicitor*. The *Constructor* style was characterized by the parent using similar numbers of questions, statements, and confirmations. In contrast, the *Elicitor* style was characterized by asking many questions and providing a lot of confirmations but providing few statements. Parents who adopted an *Elicitor* style had children who contributed more to the conversation (specifically, provided more statements) compared to parents who adopted a *Constructor* style.

Parental book-sharing styles also relate to children's literacy skills. In a sample of White, middle-class mothers and their children, maternal book-sharing at age 3 was characterized into three styles: the *Describer*, the *Comprehender*, and the *Collaborator* (Haden et al., 1996). Mothers in the *Describer* group made the most statements related to describing and labeling objects in the picture, mothers in the *Comprehender* group made the most statements about print knowledge, and mothers in the *Collaborator* group made the most confirmations of the child's statements. Parents who utilized the *Comprehender* style had children with the highest story comprehension and receptive vocabulary two years later and parents who utilized the *Collaborator* style had children with the highest decoding skills two years later.

In another study of book-sharing, low-income Latino mothers and their 4- to 5-year-old children were observed sharing a wordless picture book together (Caspe, 2009). Mothers were classified as being *Storybuilder-labelers* or *Storytellers*. The *Storybuilder-labelers* asked the most questions and provided some statements, while *Storytellers* provided the most statements and asked some questions. The *Storyteller* style was positively associated with children's print-related literacy skills compared to the *Storybuilder-labeler* style.

Studies on parental styles have not only focused on book-sharing but also other contexts. For example, a study identified parental styles during the teaching of a novel word with slightly younger children (Wei et al., 2019). White, college-educated parents were asked to teach a novel word to their toddler. Two styles of parental support during the task were identified: the *Cognitive Scaffolder* and the *Labeler*. In the *Cognitive Scaffolder* style, parents used a balance of asking questions and providing statements to the child, while also providing some challenging support to the child to help scaffold beyond their abilities. The *Labeler* parents provided mostly statements. Children of *Cognitive Scaffolder* parents had higher word recognition skills than children of *Labeler* parents.

In response to this prior research, the current study contributes to the literature in three primary ways. First, it explores whether the styles of language that parents use with their children when engaging in shared book reading, novel word learning, and reminiscing are present in the math language parents use with their children during a picture-sharing task. Several of the samples in these past studies were similar to the sample of the current study, suggesting the likelihood that parents will use similar types of support across these studies. The evidence presented has already demonstrated that parents use similar types of questions, statements, and confirmations in math support as those that have been documented in the language and literacy literature and these math language types are associated with children's math talk and math skills, so there is support for the possibility that language styles will also be present in parental math language and will relate to children's math variables.

Secondly, none of the studies examining parental language styles in language and literacy compared a variable-centered approach to a person-centered approach. They each focused specifically on identifying parental language styles without capturing why empirically a person-centered approach is a better reflection of parental support and a better predictor of child variables than a variable-centered approach. These studies showed how combinations of questions, statements, and confirmations are valuable in predicting children's language and literacy skills, but they are only theoretically capable of arguing that these styles are a preferred approach.

Third, these studies use all the utterances made during the task to create their styles, rather than focusing only on domain-specific utterances. However, no study to date has used this person-centered approach on math talk compared to general language talk to determine whether parents use the same style when they talk about math vs. when they talk more generally. By comparing parental math talk (i.e., utterances about math) to general language talk (i.e., utterances not about math), it is possible to explore the stability and domain-specificity of parental language styles in order to consider whether parents are using a style only when they talk about math, or whether the style is also used during overall general language conversations.

1.6 Current Study

The current study investigated the relations between parental math language styles and children's math performance. Because the person-centered approach is relatively new in the math development field, I also explored whether similar results were obtained if using a more common approach (frequencies of parental math language types) and whether results extended to parental general language talk and to child general language talk and language skills. Specifically, this study addressed the following research questions:

1. What math language *styles* do parents adopt in a picture-sharing task?

Given that prior work on parental math language has not adopted a person-centered approach, I do not propose any a priori hypotheses regarding which styles parents will adopt. However, it is possible that they will adopt styles similar to those documented by prior literature on book-sharing and literacy development (e.g., a style that focuses on providing a variety of supports in similar amounts vs. a style that privileges some supports over other, such as focusing on providing statements to the child). However, it is also possible that other styles will be identified.

2. Are parental math language styles related to children's math talk, math skills, general language talk, and language skills?

Based on prior literature (Caspe, 2009; Melzi et al., 2011), I expect that some parental styles would promote more child verbal contributions (math talk) during the picture-sharing task and relate to higher math skills than others. If I find styles similar to those documented by prior literature on literacy development (e.g., a style that focuses on providing a variety of supports in similar amounts vs. a style that privileges some supports over other, such as focusing on providing statements to the child), then I expect that a style that provides a variety of supports will positively relate to children's math talk and math skills. I do not expect math language styles will differ in children's general language talk or language skills, as I predict they will only relate to more domain-specific variables. Although the current study is not designed to address the directionality of these relations, I expect these results because a parent who uses a combination of questions, statements, and confirmations promotes the child's participation in the conversation by asking questions, providing information, and confirming the child's contributions, which should increase child talk and support children's math learning.

3. Is *frequency* of parental math language types related to children's math talk, math skills, general language talk, and language skills?

Based on prior literature (Duong et al., 2021; Eason et al., 2021) that illustrates that parental questions and statements are related to children's math talk, I expect that these math language types will be associated with higher child math talk and skills. I do not have a priori hypotheses about the associations between parental math confirmations and children's math talk and skills, as these relations have not yet been explored.

4. Are parental *general language* styles related to children's math talk, math skills, general language math talk, and language skills?

Although no studies have explicitly explored relations between parental general language talk and children's math talk and skills, I hypothesize that parents' general language styles may relate to children's math talk and math skills given the past literature demonstrating associations between math and language domains (Purpura et al., 2011; Slusser et al., 2019).

2.0 Method

2.1 Participants

This study used data from a larger longitudinal study of the effects of a math intervention on parent-child math conversations during daily family routines. For the purposes of the current study, data at pre-test (before intervention) on parents and children from the larger study were included. The current study included 76 preschool children and their primary caregiver. Children ranged in age from 48-60 months (M = 53.32, SD = 3.40) and 45% were female. Ninety-six percent of the primary caregivers were mothers, 87% had at least a four-year college degree, 87% were White, and 48% had a monthly household income of greater than $6,000. Participants were recruited through an institutional recruitment site, social media postings, and word of mouth communications to local childcare centers and parenting groups. To be eligible to participate, children had to be four years old at the start of the study and could not have an intellectual or learning disability. Families had to be fluent in English and live in the United States.

2.2 Measures and Procedures

During two 20–30-minute virtual sessions on a videoconference call, parents and children completed a picture-sharing task and children completed a battery of math and language assessments. These two sessions took place between one day and a week and a half apart. Dyads completed the picture-sharing task followed by the math assessments in the first session, and the language assessments during the second session.

2.2.1 Picture-Sharing Task

During this task, dyads were shown a picture on the screen during the videoconference call. The researcher told the parent and the child to talk about the picture together like they normally would for five minutes. The researcher began the recording and turned off their own video and audio so they would not distract the dyad during the task. The researcher set a timer for five minutes and after five minutes, the researcher returned, told the dyad their time was up, and stopped the recording. Dyads were randomly assigned to see one of the following pictures: farm, living room, jungle, or kitchen. This task was chosen because it was most similar to the wordless picture book tasks utilized in prior language and literacy studies using person-centered approaches. The four images used in this task are included in Appendix A.

2.2.2 Math Assessments

Two math assessments were administered: the Preschool Early Numeracy Scale (Purpura & Lonigan, 2015) and the Early Patterning Assessment (Rittle-Johnson et al., 2020). The Preschool Early Numeracy Scale (PENS) included four subscales measuring the following math abilities: One-to-One Counting/Cardinality, Set Comparison, Numeral Identification, and Story Problems. The Early Patterning Assessment measures children's ability to identify whether a set of objects makes a pattern, what object is missing in a pattern, and what objects come next in a pattern.

In the One-to-One Counting/Cardinality subscale, children were shown three sets of between six and 18 dots. Children were asked to count the dots, then say how many dots there were. In the Set Comparison subscale, children were shown four sets of dots at a time, each set with between zero and 13 dots. Children were asked to indicate which set had the most dots for two items and the least dots for two items. For the Set Comparison items, the child was not explicitly told to solve without counting the dots. In the Numeral Identification subscale, children were shown three single-digit and two double-digit written numbers from one to 20 and asked to provide the name of the number. In the Story Problems subscale, children were verbally told two stories with addition problems and two stories with subtraction problems, each with numbers from zero to four. They were asked to provide the answer to the math problem in the story.

In the Early Patterning Assessment, children were shown two different sets of colored squares and asked to indicate whether the squares made a pattern. In the second part of the assessment, they were presented with two different patterns of pictures with a blank in the pattern. Children were asked to indicate which of three pictures was missing from the pattern. In the third part, children were shown two different patterns with a blank at the end and they were asked to indicate which of three sets of pictures would go next in the pattern.

Scores from both assessments were aggregated together to create one sum score of math skills, calculated as a percent correct of all total math items.

2.2.3 Language Assessments

Two language assessments were administered: the Receptive One Word Picture Vocabulary Test-4th Edition (Martin & Brownell, 2011) and the International Development and Early Learning Assessment (Save the Children, 2017). The Receptive One Word Picture Vocabulary Test (ROWPVT) was used to measure receptive vocabulary and the International Development and Early Learning Assessment (IDELA) was used to assess children's expressive vocabulary.

In the ROWPVT, the researcher shared their screen in the videoconference call and showed the child sets of four pictures with the numbers one to four above them. The researcher said a word and asked the child to indicate the number that went with the picture of that word. The researcher began at the appropriate item for the child's age and then moved forward and backward through the items until the child established a basal, as indicated by eight consecutive correct responses. The researcher then continued until the child reached a ceiling level, as indicated by six incorrect responses in eight consecutive items. Raw scores were calculated as the number of errors made in the assessment subtracted from the child's established ceiling (from 0 to 190).

In the IDELA, the researcher asked the child to imagine they were going to a grocery store or supermarket and to list foods they might buy there. For the second item, the researcher asked the child to list the names of animals that they know. The child was stopped after reaching 10 items for each question. If the child stopped before reaching 10 items, the researcher asked one time if the child could think of any others. The IDELA has been shown to have high internal consistency, reliability, and construct validity (Pisani et al., 2018). Scores were calculated as the percentage of items out of 20 possible items that the child provided.

2.3 Coding

Video recordings of the picture-sharing task were transcribed and coded at the utterance level. Five research assistants were trained by the author to transcribe the video recordings by completing two transcripts and then meeting with the author to resolve discrepancies. Each transcript was completed by one of the research assistants and checked by a second research assistant. Transcripts were coded by either the author or one of four research assistants who were trained in the coding scheme. The research assistants initially coded four transcripts independently, and then met with the author to discuss and resolve disagreements. The five coders independently coded the same 25% of the transcripts and achieved reliabilities of Cohen's kappa ranging from 0.67-0.94 across parent and child utterances. The remaining 80% of transcripts were independently coded by one of the five coders.

2.3.1 Parental Utterances

Transcripts were coded at the utterance level for **type** of parental math talk. Each utterance was coded based on four mutually exclusive categories used in prior literature: question, statement, confirmation, and other (Melzi et al., 2011; Ramani et al., 2015). Questions were coded as any utterance ending in a question mark, or an utterance that provided the other speaker the opportunity to respond, even if the question was not completed. An example of a math question is "How many trains do you see?" and an example of a general language question is "What color is the cow?" Statements were coded as any utterance that added new content to the conversation and was not a question. An example of a math statement is "One banana and two oranges make three fruits" and an example of a general language statement is "The sun is rising behind the mountain." Confirmations were coded as utterances that maintained the flow of conversation and did not add any new information, including repetitions of something the other speaker already said. An example of a math confirmation is "Three monkeys" after the other speakers says, "Three monkeys" and an example of a general language confirmation is "Hmm okay." See Table 1 for more detailed definitions and examples. Parental utterances were also coded for **content** depending on whether they contained math. See Table 2 for definitions and examples.

Table 1. Definitions and Examples of Type Utterance Categories

Utterance Type	Definition	Example
Question	Probing for information; can be open-ended or closed-ended	What's in the bowl?
Statement	Providing new information or a rationale or causal link related to the task	I see three monkeys.
Confirmation	Maintaining the flow of the conversation but not adding any new information	Really?
Other	Vocalizations, non-verbal utterances, and utterances not clear enough to be transcribed	[laughing]

Table 2. Definitions and Examples of Content Utterance Categories

Utterance Type	Definition	Example
Counting	Asking someone to count or using a counting sequence	Can you count these?
Cardinality	Asking someone to label a set or labeling a set	I see four blocks.
Set comparison	Asking someone to make a comparison or stating a comparison	Which horse is bigger?
Number identification	Asking someone to identify numbers or recognizing a written number	That's a six.
Adding/subtracting	Asking someone to solve an addition/subtraction problem or stating an addition/subtraction problem	How many birds would there be if one flew away?
Patterning	Asking someone about a pattern or making an observation about a pattern	Blue would come next.

2.3.2 Child Utterances

Based on the coding scheme used with parental utterances, all child utterances were also coded for **type** (question, statement, confirmation, or other), and **content** (whether the utterance included math).

2.4 Analytic Plan

To identify parental math language styles, I conducted hierarchical clustering analyses with Ward's linkage method and squared Euclidean distances to identify the appropriate number of clusters (MacArthur et al., 2012). The number of clusters was determined by visually inspecting the dendrograms and considering the following indices: the cubic clustering criterion, the pseudo-*F* (Caliński & Harabasz, 1974), and the pseudo t^2 (Duda & Hart, 1973). Variables used were mean proportions (frequencies of each variable as the proportion of the total number of math utterances) for parental math questions, statements, and confirmations. Next, I used partitioning clustering analyses (k-means iterative) to improve the assignment of parents to clusters. The k-means algorithm was run 1,000 times for each cluster solution (Steinley, 2003) and compared to the stopping rules of Caliński & Harabasz (1974) to determine the final cluster solutions. The Rand index and predictive discriminant analysis were used to test the stability, robustness, and validity of the cluster solutions (Hammett et al., 2003). Next, I performed Analyses of Variances (ANOVAs) with post-hoc Tukey tests to examine differences in demographics and parental math language types between styles.

All OLS regression analyses controlled for the same set of covariates. To determine this set of covariates, I performed a series of Pearson's correlations and semi-partial correlations. See Appendix B. These analyses revealed that the following variables were related to at least one of the child talk and skills variables: child age, parent having a 4-year college degree, child receptive vocabulary, parent total utterances, and child total utterances. To estimate the size of the associations, I calculated standardized associations by dividing the unstandardized beta coefficients of the predictor by the standard deviation of the variable.

To determine associations between parental math language styles and children's math and language variables, I used Ordinary Least Square (OLS) regression analyses to determine if parental math styles (predictor) are associated separately with children's math talk, math skills, general language talk, and language skills, controlling for covariates. To determine associations between frequencies of parental math language types and children's math and language variables, I conducted OLS regressions with each of the three parental math language types (questions, statements, and confirmations) and each of the four child variables, controlling for covariates. Finally, to identify parental general language styles and determine associations between these general language styles and children's math and language variables, I conducted hierarchical clustering analyses and k-means partitioning clustering analyses using parent general language questions, statements, and confirmations as proportions of the total number of parental general language utterances. I conducted ANOVAs with post-hoc Tukey tests to examine differences in demographics and parental general language types between styles and conducted OLS regressions with the styles as predictors with each of the four child variables, controlling for covariates.

3.0 Results

3.1 Descriptive Statistics

Table 3 summarizes the descriptive statistics for relevant parent and child variables. On average, parents spoke 107 total utterances during the five-minute picture-sharing task, with an average of 12 utterances about math (11% of total parent utterances). Children spoke an average of 74 total utterances with an average of nine utterances about math (13% of total child utterances). Table 3 also includes raw scores for children's math skills (percent correct), receptive vocabulary, and expressive vocabulary (percent of total items).

Table 3. Descriptive Statistics for Child Variables and Parent and Child Talk Variables

	Mean	SD	Range	Skewness
Child Variables				
Math	58.22	20.33	16.67 – 100	-0.02
Receptive vocabulary	64.28	21.01	1 – 103	-1.00
Expressive vocabulary	55.80	27.19	0 – 100	-0.17
Parent and Child Talk				
Parent total utterances	106.96	19.75	65 – 174	0.49
Parent math utterances	12.36	8.14	1 – 35	0.75
Child total utterances	74.33	14.02	36 – 105	-0.04
Child math utterances	9.16	6.12	0 – 25	0.56

Note. Child math score represents percentage of correct answers and child expressive vocabulary score represents percentage of total items.

3.2 Parental Math Language Styles

Results of clustering analyses with parental math language yielded that the optimal and meaningful solution was three clusters: pseudo-t^2= 38.08, pseudo-F = 55.24. The Rand index between the three-cluster and four-cluster solutions was .79, indicating sufficient agreement on the assignment of individuals to clusters (Caspe, 2009). Box's test revealed significant covariance matrix differences among clusters in the three-cluster solution, $F(6, 21963.4) = 6.07$, $p < .001$ indicating that the assumption of equal covariance matrices was not met (Hammett et al., 2003). As a result, quadratic predictive discriminant analyses using the leave-one-out classification method were used. The overall hit rate for the three-cluster solution was 94.7%, with the hit rates for each individual cluster as follows: Cluster 1 = 89.74%, Cluster 2 = 100%, Cluster 3 = 100%. These results indicate that the cluster solution offers valid groupings for these data. These cluster hit rates were higher than has been found in prior literature (Hammett et al., 2003).

Cluster 1 was adopted by 51% of the total sample (n = 39). Parents in Cluster 1 focused on requesting (44% of math utterances were questions) and providing math information (41% of math utterances were statements), while sometimes maintaining the flow of the conversation (15% of math utterances were confirmations). This style was labeled as the *Math Discusser*. Cluster 2 was adopted by 20% of the total sample (n = 15). Parents in Cluster 2 focused on providing math information (75% of math utterances were statements), while requesting some math information (22% of math utterances were questions) and rarely maintaining the flow of the conversation (3% of math utterances were confirmations). This style was labeled as the *Math Commentator*. Cluster 3 was adopted by 29% of the total sample (n = 22). Parents in Cluster 3 focused on requesting math information (75% of math utterances were questions), while providing some math information (17% of math utterances were statements), and sometimes maintaining the flow of the conversation (9% of math utterances were confirmations). This style was labeled as the *Math Elicitor*. Figure 1 summarizes the proportions of the three math language types for each of the three styles.

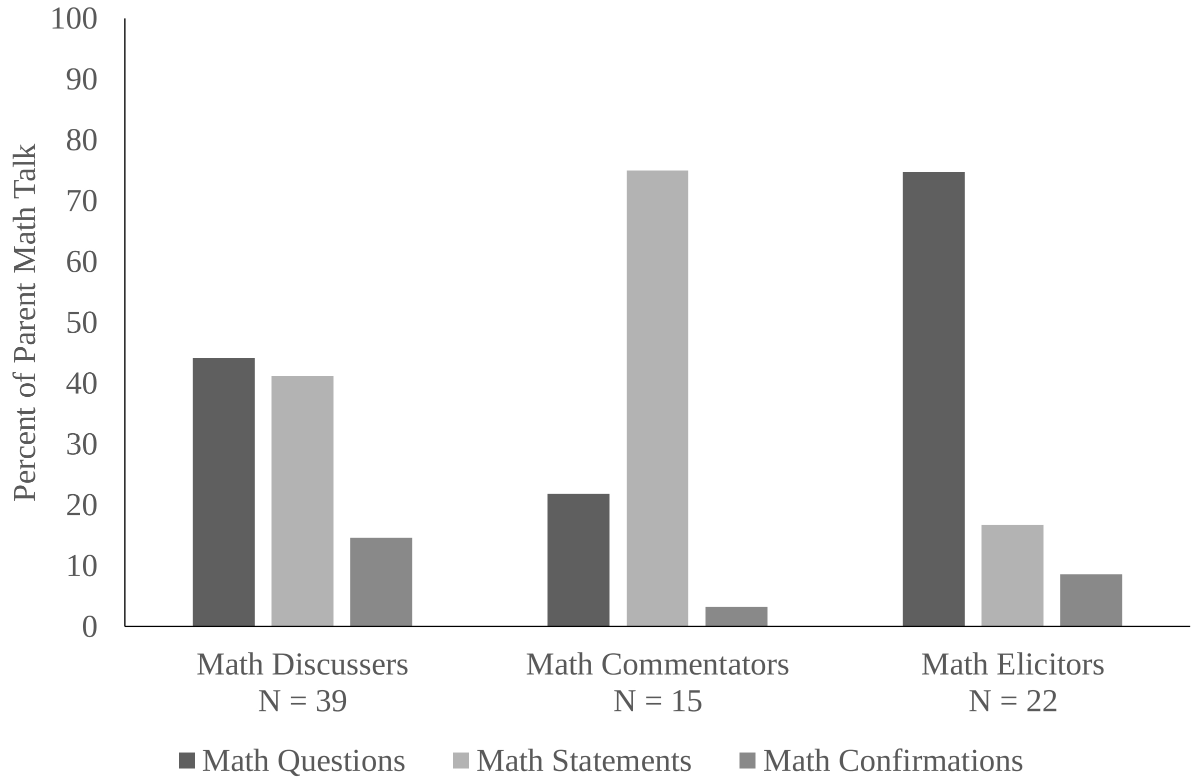

Figure 1. Frequencies of Math Language Types in Math Language Styles

Results of ANOVAs are presented in Table 4 (demographics) and Table 5 (math language types). There were no significant differences in parent or child demographics between the three clusters. Math Elicitors asked more math questions than Math Discussers or Math Commentators, $F(2,73) = 76.15$, $p < .001$. Math Commentators provided more math information (math statements) than Math Discussers or Math Elicitors, $F(2,73) = 106.66$, $p < .001$). Math Discussers maintained the flow of the conversation more (math confirmations) than Math Commentators, but not more than Math Elicitors, $F(2,73) = 3.60$, $p = .032$).

Table 4. Results of ANOVAs for Demographics in Math Language Styles

	Math Discussers	**Math Commentators**	**Math Elicitors**
	M (SD)	**M (SD)**	**M (SD)**
Child Age	53.85 (3.42)	51.76 (2.72)	53.44 (3.58)
Child Gender	0.47 (0.51)	0.40 (0.51)	0.45 (0.51)
Child Receptive Vocabulary	67.47 (19.46)	61.53 (24.57)	60.64 (21.16)
Parent Age	36.63 (3.86)	35.69 (3.17)	37.02 (4.34)
Parent Education	0.87 (0.34)	0.87 (0.35)	0.86 (0.35)

Note: Child age is measured in months, child gender is measured as a dummy variable representing child as female, parent age is measured in years, and parent education is measured as a dummy variable representing parent having at least a 4-year college degree.

Table 5. Results of ANOVAs for Frequencies of Math Language Types in Math Language Styles

	Math Discussers	**Math Commentators**	**Math Elicitors**
	M (SD)	**M (SD)**	**M (SD)**
Math Questions	44.23 (12.72)	21.80 (12.49)	74.80 (14.51)***
Math Statements	41.21 (10.11)	75.00 (13.94)***	16.65 (13.44)
Math Confirmations	14.57 (18.06)*	3.20 (5.09)	8.55 (11.47)

Note. *p < .05, **p < .01, ***p < .001.

3.3 Relations between Parental Math Language Styles and Child Talk and Skills

Table 6 presents the results of the OLS regressions testing for associations between parental math language styles and child math and language variables. Below I summarized the results and discuss the size of the associations (based on their standardized betas).

3.3.1 Child Math Talk

Math Discussers were more likely to have children who talked more about math than Math Commentators, but with no difference in child math talk compared to Math Elicitors. The size of the association was small to medium.

3.3.2 Child Math Skills

There were no significant associations between parental math language styles and children's math skills.

3.3.3 Child General Language Talk

Math Discussers were more likely to have children who talked about less about general language math than Math Commentators, but with no difference in child general language talk compared to Math Elicitors. Compared to Math Commentators, Math Elicitors were more likely to have children who spoke more overall. The size of the associations was small to medium.

3.3.4 Child Language Skills

There were no significant associations between parental math language styles and children's receptive or expressive vocabulary skills.

3.4 Relations between Frequencies of Parental Math Language Types and Child Talk and Skills

Table 7 presents the results of the OLS regressions testing for associations between frequencies of parental math language types and child math and language variables. Below I summarized the results and discuss the size of the associations (based on their standardized betas).

Table 6. Results of OLS Regressions with Math Language Styles and Child Variables

	Child Math Talk			Child Math Skills			Child General Language Talk			Child Receptive Language Skills		
	β	B	SE	β	B	SE	β	B	SE	β	B	SE
Math Commentators	-.26*	-5.62	2.81	-.02	-1.25	4.78	.26*	5.62	2.81	-.08	-4.14	6.52
Math Elicitors	-.18	-3.46	2.36	.05	2.23	4.01	.18	3.46	2.36	-.13	-5.80	5.45

Note. **p* < .05; The reference group is Math Discusser. All analyses are controlling for child age, parent education, child receptive vocabulary, and parent and child total utterances.

Table 7. Results of OLS Regressions with Frequencies of Math Language Types and Child Variables

	Child Math Talk			Child Math Skills			Child General Language Talk			Child Receptive Language Skills		
	β	B	SE	β	B	SE	β	B	SE	β	B	SE
Math Questions	-.03	-0.01	0.05	.12	0.10	0.08	.03	0.01	0.05	-.09	-0.08	0.11
Math Statements	-.02	-0.01	0.05	.00	0.00	0.08	.02	0.01	0.05	.07	0.06	0.11
Math Confirmations	.07	0.04	0.07	-.18*	-0.24	0.11	-.07	-0.04	0.07	.04	0.05	0.16

Note. **p* < .05; All analyses are controlling for child age, parent education, child receptive vocabulary, and parent and child total utterances.

3.4.1 Child Math Talk

There were no significant associations between frequency of parental math questions, statements, and confirmations and children's math talk.

3.4.2 Child Math Skills

There were no significant associations between frequency of parental math questions and statements and children's math skills. However, there was a significant association between frequency of parental math confirmations and children's math skills, such that more parental math confirmations were associated with lower math skills. The size of the association was small.

3.4.3 Child General Language Talk

There were no significant associations between frequency of parental math questions, statements, and confirmations and children's general language talk.

3.4.4 Child Language Skills

There were no significant associations between frequency of parental math questions, statements, and confirmations and children's receptive or expressive vocabulary skills.

3.5 Parental General Language Styles

Results of clustering analyses with parental general language yielded that the optimal and meaningful solution was three clusters: pseudo-t^2= 21.30, pseudo-F = 68.28. The Rand index between the two-cluster and three-cluster solutions was .71, indicating sufficient agreement on the assignment of individuals to clusters (Caspe, 2009). Box's test did not reveal significant covariance matrix differences among clusters in the three-cluster solution, $F(12, 24643.4) = 1.53$, $p = .107$, indicating that the assumption of equal covariance matrices was met (Hammett et al., 2003). As a result, linear predictive discriminant analyses using the leave-one-out classification method were used. The overall hit rate for the three-cluster solution was 98.7%, with hit rates for each specific cluster as follows: Cluster 1 = 100%, Cluster 2 = 95.83%, Cluster 3 = 100%. These results indicate that the cluster solution offers valid groupings for these data. These cluster hit rates were also higher than has been found in prior literature (Hammett et al., 2003).

Cluster 1 was adopted by 37% of the total sample (n = 28). Parents in Cluster 1 focused on requesting (35% of general language utterances were questions) and providing general language information (33% of general language utterances were statements), while maintaining the flow of the conversation (25% of general language utterances were confirmations). This style was labeled as the *General Language Discusser*. Cluster 2 was adopted by 32% of the total sample (n = 24). Parents in Cluster 2 focused on providing general language information (47% of general language utterances were statements), while requesting some general language information (30% of general language utterances were questions) and sometimes maintaining the flow of the conversation (17% of general language utterances were confirmations). This style was labeled as the *General Language Commentator*. Cluster 3 was adopted by 32% of the total sample (n = 24). Parents in Cluster 3 focused on requesting general language information (48% of general language utterances were questions), while providing some general language information (22% of general language utterances were statements), and sometimes maintaining the flow of the conversation (25% of general language utterances were confirmations). This style was labeled as the *General Language Elicitor*. Figure 2 summarizes the proportions of the three math language types for each of the three styles.

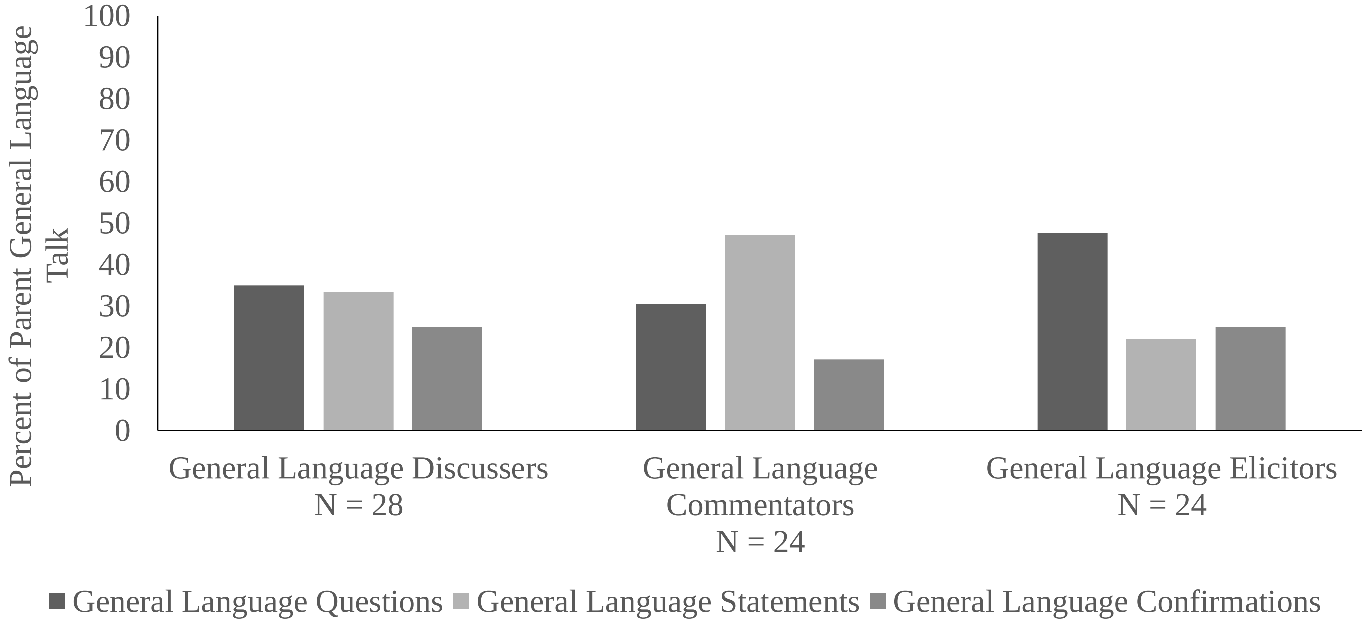

Figure 2. Frequencies of General Language Types in General Language Styles

Results of ANOVAs are presented in Table 8 (demographics) and Table 9 (general language types). There were no significant differences in parent or child demographics between the three clusters. General Language Elicitors asked more general language questions than General Language Discussers or General Language Commentators, $F(2,73) = 59.11$, $p < .001$). General Language Commentators provided more general language information (general language statements) than General Language Discussers or General Language Elicitors, $F(2,73) = 179.69$, $p < .001$). General Language Discussers and General Language Elicitors maintained the flow of the conversation more (general language confirmations) than General Language Commentators, $F(2,73) =13.71$, $p < .001$).

3.6 Relations between Parental General Language Styles and Child Talk and Skills

Table 10 presents the results of the OLS regressions testing for associations between parental general language styles and child math and language variables. Below I summarized the results and discuss the size of the associations (based on their standardized betas).

Table 8. Results of ANOVAs for Demographics in General Language Styles

	General Language Discussers	General Language Commentators	General Language Elicitors
	M (SD)	**M (SD)**	**M (SD)**
Child Age	53.13 (3.28)	53.58 (3.43)	53.27 (3.61)
Child Gender	0.52 (0.51)	0.46 (0.51)	0.38 (0.49)
Child Receptive Vocabulary	63.93 (24.45)	66.96 (18.17)	62.00 (20.02)
Parent Age	36.34 (3.88)	37.01 (4.46)	36.45 (3.38)
Parent Education	0.85 (0.36)	0.83 (0.38)	0.92 (0.28)

Note: $*p < .05$; Child age is measured in months, child gender is measured as a dummy variable representing child as female, parent age is measured in years, and parent education is measured as a dummy variable representing parent having at least a 4-year college degree.

Table 9. Results of ANOVAs for Frequencies of General Language Types in General Language Styles

	General Language Discussers	General Language Commentators	General Language Elicitors
	M (SD)	**M (SD)**	**M (SD)**
General Language Questions	35.05 (4.78)	30.50 (6.93)	47.68 (5.29)***
General Language Statements	33.36 (3.56)	47.17 (4.86)***	22.13 (5.31)
General Language Confirmations	25.00 (6.34)***	17.10 (4.96)	25.01 (6.87)***

Note: Child age is measured in months.

Table 10. Results of OLS Regressions with General Language Styles and Child Variables

	Child Math Talk			Child Math Skills			Child General Language Talk			Child Receptive Language Skills		
	β	B	SE	β	B	SE	β	B	SE	β	B	SE
General Language Commentators	-.18	-3.35	2.60	-.09	-3.78	4.34	.18	3.35	2.60	-.01	-0.28	5.99
General Language Elicitors	-.17	-3.21	2.50	-.07	-2.92	4.17	.17	3.21	2.50	-.08	-3.49	5.74

Note. The reference group is General Language Discusser. All analyses are controlling for child age, parent education, child receptive vocabulary, and parent and child total utterances.

3.6.1 Child Math Talk

There were no significant associations between parental general language styles and children's math talk.

3.6.2 Child Math Skills

There were no significant associations between parental general language styles and children's math skills.

3.6.3 Child General Language Talk

There were no significant associations between parental general language styles and children's general language talk. However, compared to General Language Commentators, General Language Discussers and General Language Elicitors were more likely to have children who spoke more overall. The size of the associations was small to medium.

3.6.4 Child Language Skills

There were no significant associations between parental general language styles and children's receptive or expressive vocabulary skills.

3.7 Additional Analyses

Because the parental math language styles were also found in the general language styles, additional descriptive analyses were conducted to compare participants' math language style membership to their general language style membership (see Table 11 for more details). Math Discussers were equally likely to be General Language Discussers, Commentators, and Elicitors. Similarly, Math Elicitors were equally likely to be General Language Discussers and Elicitors but were much less likely to be General Language Commentators. On the other hand, almost all Math Commentators were also General Language Commentators.

Table 11. Comparison of Parental Styles Across Math Language and General Language

General Language Styles	Math Language Styles		
	Discussers (N = 39)	Commentators (N = 15)	Elicitors (N = 22)
Discussers (N = 28)	16	3	9
Commentators (N = 24)	10	11	3
Elicitors (N = 24)	13	1	10

Note. Values represent number of parents in each combination of math language style and general language style.

4.0 Discussion

The current study shows that parents vary in the math language styles they adopt during a picture-sharing task, and that this variation related to their children's math talk but not to math skills, general language talk, or language skills. Importantly, alternative approaches (focusing on frequencies of parental math language or parental general language styles) yielded, for the most part, null associations with child math variables. Below I discuss each of these sets of styles and frequencies separately.

The current study identified three styles of parental math language: Math Discusser, Math Commentator, and Math Elicitor. The first style involved a balance of math language types, while the other two styles privileged one type of math language over the others. Parents who adopted a Math Discusser style promoted math conversation with their child by using some math requests, providing some math information, and using some math confirmations. In the field of language and literacy, this style has also been called a Constructor style (Melzi et al., 2011), a Storybuilder-labeler style (Caspe, 2009), and an Interactive style (Nieto et al., 2019). Unlike these language/literacy styles which often used a similar number of confirmations to questions and statements, the Math Discussers in the current study used many fewer math confirmations than math questions and math statements. Parents demonstrating this style may view themselves as egalitarian conversational partners with their child, balancing their own contributions with the contributions of their child.

Parents who adopted a Math Commentator style focused on providing math information while doing little to request math information from their child or maintain the flow of conversation. This style has also been called a Storyteller style (Caspe, 2009) and an Information Provider style (Nieto et al., 2019). These parents may view themselves as the source of knowledge, focusing less on creating opportunities for their child to participate in the conversation and more on providing their own information.

Finally, parents who adopted a Math Elicitor style often requested math information from the child while utilizing fewer math statements and math confirmations. This style has also been called an Elicitor style (Leyva & Nolivos, 2015; Melzi et al., 2011) and an Information Requester style (Nieto et al., 2019). Parents in this style may view the conversation as an opportunity to determine what their child knows, dominating the conversation with questions rather than engaging in a mutual conversation with their child.

Associations between parental math language styles and children's math talk were found. Math Discussers were more likely to have children who spoke more about math than Math Commentators. However, despite talking more about math, there were no differences in children's math skills between Math Discussers, Commentators, and Elicitors. Math Elicitors devoted a greater percentage of utterances to asking math questions than other styles (75% vs. 22-44% of total math utterances), which might suggest a greater encouragement of children's participation in a math conversation, but instead there was no difference in math talk between children of Math Elicitors and Math Discussers. These results support the hypothesis that using a balance of math language types promotes more child math talk, but does not support the hypothesis that these balanced styles relate to advanced math skills.

One possible explanation for these results is that Math Discussers are using a variety of math utterance types in order to encourage their child to participate more in a math conversation. Some research has suggested that, when parents are using a style that incorportates a balance of questions, statements, and confirmations, they are giving the child multiple opportunities to engage in the conversation, which has been related to higher number of child elicited and spontaneous utterances (Nieto et al., 2019). Parents preparing their children for school in the United States may take on this style of language in order to replicate the emphasis placed on discussion and scaffolding in American schools (Caspe, 2009). Despite evidence suggesting that parental math questions are associated with higher math talk and math skills (Duong et al., 2021; Eason et al., 2021), math talk was just as high in children of Math Discussers as it was in children of Math Elicitors. These results suggest that it is the balance of math utterance types that most strongly encourages the child's participation in the conversation and not the overall number of questions. Additionally, there were no relations between parental math language styles and children's math skills. Although this is suprising given evidence that parental language styles are related to children's language and literacy skills (Caspe, 2009; Haden et al., 1996), it suggests that parental math language styles may not have the same relation to child math skills. One possible explanation for this lack of association is that the parents' math language during the picture sharing task was more focused on counting and labeling sets of objects, while the math assessments also measured skills in set comparison, number identification, adding and subtracting, and patterning. Additionally, there were no differences in these styles on demographic variables, suggesting that differences in math talk between children of Math

Discussers and Math Commentators is not likely due to other parent or child factors. It is also interesting that Math Commentators and Math Elicitors, the two styles with the most drastically different parental math language make-up, show no differences in children's talk and skills. Despite these differences, the conceptual representation of the role of the parent and child in these two groups is the same. In these styles, the parent holds one role (either information provider or information requester) while the child holds a different role (either information receiver or information provider). However, in dyads with a Math Discusser, the parent and child both play an active, reciprocal role in maintaining the conversation and contributing their own information. These results suggest that this mutual relationship is more strongly associated with children's math contributions.

Notably, prior work examing the relations between parental language/literacy styles and children's talk and skills have yielded mixed results. For example, two studies have found that children of parents who ask mostly questions spoke more compared to children of parents in other styles (Leyva & Nolivos, 2015; Melzi et al., 2011). However, one study found that children of parents with a balanced style spoke more than children of parents who used mostly statements (Nieto et al., 2019). Another study found that the style that used the most confirmations had children with higher literacy skills (Haden et al., 1996) while another found that the style that used a balance of questions and statements had children with higher language skills (Wei et al., 2019). Taken together, these mixed results might suggest that these relations are context- and domain-specific, thus there is not a single style that is consistently related to children's talk and skills across situations.

Math Discussers also had children who spoke less about general language compared to Math Commentators, but this is not surprising given the fact that children's math and general language were measured as percentages of their overall number of utterances. As a result, talking for a larger percentage of the time about math subsequently means the percentage of time spent talking about general language will be smaller. There was also no difference in children's language skills by parental math style. Although some research suggests that parental language during a book-sharing task is related to children's math skills (Ribner et al., 2020), the results of the current study suggest that the opposite is not true; parental math language is not related to children's language skills. Although children's language and math performance are strongly interconnected (Purpura et al., 2011; Slusser et al., 2019), the pattern of math language that parents use seemingly only has implications for children's math talk.

There were no relations between frequencies of parental math questions and statements and any of the child math and language variables. However, there was a negative association between frequency of parental math confirmations and children's math skills, such that parents who used more math confirmations had children with lower math skills. Using more math confirmations may be limiting the new math information the child hears, which might relate to lower math skills. Alternatively, parents may be using more math confirmations with children with lower math skills to meet them where they are and reinforce their learning. Parents provide more instruction and modeling to high-ability children compared to low-ability children during a math game (Bjorklund et al., 2004), suggesting that parents of high-ability children may be more aware of their children's needs and more able to provide them with supportive feedback than parents of low-ability children during a math conversation. Overall, these results are in line with prior research showing that parental math support at home (whether reported or observed) is not always positively related to children's math performance (De Keyser et al., 2020; Duong et al., 2021; Missall et al., 2015; Son & Hur, 2020). Taken together, these results seem to suggest that taking a person-centered approach might be a promising way to understand the nuances of parental math support at home. By focusing on the different ways that parents combine math language types rather than just on the overall frequencies of these types, researchers can better understand the complexity of parental math support and the implications of this support for children's math learning.

The three styles identified in parental math language were also present in general language, with one style using a balance of language types (General Language Discussers), one style that privileged statements over other language types (General Language Commentators), and one style that privileged questions over other language types (General Language Elicitors). However, there were no associations between these styles and children's math talk or math skills. These results suggest that, although parents vary in the type of support they provide in general language conversations, these styles do not promote domain-specific math talk or math skills.

No prior work has studied associations between parental general language talk and children's math skills, but one study did find that parents' distancing language during a book-sharing task was related to children's math skills (Ribner et al., 2020). The current study found that General Language Discussers and General Language Elicitors were more likely to have children who spoke more overall compared to General Language Commentators, suggesting that when parents provide mostly statements, children are less likely to participate in the conversation. Given that parental general language styles were only related to overall talk and not any math variables, these results further support the conclusion that parental math styles best explain children's math talk. Additionally, while Commentators in the current study were most likely to demonstrate the same style across math and general language, Elicitors and Discussers were not as consistent across the two types of language. These results are aligned with past literature that has found that some parents are more consistent in their language styles across contexts than others (Haden et al., 1996). These parents may have a set idea about how to talk to their child, while other parents may be more flexible in the support they are providing, adapting their language to match the needs, interests, and skills of their child at the moment. It is also important to note that parents may not be actively choosing a language style, but instead responding to their child. For example, a child who is active and engaged may start talking about the picture on their own, without the parent needing to ask them questions. As a result, the parent may occassionally add their own observations, but is much more likely to let the child take the lead. In this scenario, the parent may appear to be a Commentator not because they view themselves as the source of knowledge, but because the child has already taken the lead in guiding the conversation. Although the directionality of these associations could not be explored in the current study, recognizing the role that the child plays in influencing parental language is an important consideration.

Overall, the results of the current study suggest that a person-centered approach looking at parental math styles has the potential to better explain children's math talk compared to a variable-centered approach looking at frequencies of parental math language types or a person-centered approach looking at parental general language styles. These approaches also provide little support for explaining children's general language talk and language skills, demonstrating the domain-specificity of parental math support.

4.1 Limitations

An important limitation to this study is the homogeneity of the sample (mostly highly educated, White families). This homogeneity limits the generalizability of these results to other populations and may capture cultural expectations about talking to children about math that are not applicable in other samples. An additional concern related to including a highly educated, White sample is the limited variability and high averages in children's skills and parental talk. Despite this concern, there was a large range in children's math and language skills and parents' and children's overall and math-related talk in the current study. Another limitation is that these data were collected concurrently, which limits the capacity to see how these styles change over time. Future longitudinal studies could explore the stability of these styles across dyads and contexts. Additionally, it is not possible to conclude directionality from the current study. It is not clear that parental math language is influencing children's math talk and skills or that the child variables are influencing parental math language, just that they are associated. There may also be additional variables at play, such as parental math anxiety and math skills, that relate to both parental math language and children's math talk and math skills.

4.2 Implications and Conclusions

One valuable strength to the current study is that the data were collected in families' homes rather than in an unfamiliar lab. Although the virtual setting of the current study was necessitated by the COVID-19 pandemic and was not an intentional methodological decision, it offers a unique opportunity to explore more natural conversations between parents and children without the confines of a lab setting or the invasiveness of a researcher physically in the home of the participants. Capturing these conversations in participants' homes suggests greater generalizability to experiences in the home environment. The current study also adds to the previous research by exploring the associations between parental math language styles and children's math talk and math skills and provides evidence to expand our understanding of the relations between parental math language and 4-year-old children's math development above and beyond previous work exploring frequencies of math language types. In conclusion, the current study has built on prior literature investigating parental math language and styles of general language support to better understand the diverse ways that parents communicate with their children about math concepts, which suggests the need for future research that seeks to better capture the complexity of parental math support.

Appendix A Picture-Sharing Task Images

Figure 3. Images for Parent-Child Picture-Sharing Task

Appendix B Results of Correlations and Semi-Partial Correlations with Covariates and Child Variables

Table 12. Correlations Between Covariates and Child Variables

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Child Math Talk	--									
2. Child Math Skills	.12	--								
3. Child General Language Talk	-1.00***	-.12	--							
4. Child Receptive Vocabulary	.06	.63***	-.06	--						
5. Child Expressive Vocabulary	.13	.34**	-.13	.35**	--					
6. Child Age	.08	.31**	-.08	.34**	.21+	--				
7. Child Gender	.13	.02	-.13	-.01	-.03	-.07	--			
8. Parent Education	.07	.35**	-.07	.08	.21+	.05	.04	--		
9. Parent Total Utterances	-.10	-.31**	.10	-.17	-.31**	-.01	.03	-.10	--	
10. Child Total Utterances	-.26*	-.11	.26*	-.10	-.09	-.01	-.01	-.13	.24*	--

Note. +*p* < .10; **p* < .05; ***p* < .01; ****p* < .001; Child age is measured in months and parent education is measured as a dummy variable representing parent having at least a 4-year college degree.

Table 13. Semi-Partial Correlations of Child Language Covariates on Child Variables

Variable	**Child Receptive Vocabulary**	**Child Total Utterances**
Child Math Talk	.00	.06*
Child Math Skills	.39***	.00
Child General Language Talk	.00	.06*
Child Expressive Vocabulary	.12*	.00

Note. Partial correlations to indicate that child receptive vocabulary was related to some of the variables even after controlling for child total utterances. *$p < .05$; **$p < .01$; ***$p < .001$.

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