What's in a question? Parents' question use in dyadic interactions and the relation to preschool-aged children's math abilities

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The cognitive complexity of adults' questions, particularly during shared book reading, supports children's developing language skills. Questions can be described as having low cognitive demand (e.g., labeling, matching) or high cognitive demand (e.g., comparing, predicting). Little is known about the relation between different types of parental questioning and children's math abilities. The present study examines the quantity of low- and high-cognitive demand (CD) and domain-specific math questions that parents pose to their 4-year-old children in three structured activities, and how the frequency of those questions relates to children's concurrent math and language skills. Parent-child dyads (*n*=121) were observed interacting with a picture book, grocery store toys, and a puzzle for about 5 minutes each and children completed math and spatial assessments. Although the frequency with which parents asked questions did not relate to children's outcomes, parents' use of high-CD questions was associated with children's spatial skills, standardized math scores, and vocabulary skills after controlling for parental utterances, child utterances, child age, and family socioeconomic status. However, domain-specific math questions were not related to any child outcomes above and beyond parents' total questions. This study suggests that domain-general questions that vary in cognitive demand (low and high) are differentially related to children's math and language abilities, which can inform the ways parents engage in early learning opportunities with their children.

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Preface

We thank Leanne Elliott, Monica Navarro, Laura Betancur, Lorraine Blatt, and Kendra Whitfield for assistance with data collection. We thank Abigail Haslinger for assistance with recruitment. We thank Sarah Pitulski, Sasha Hofman, Andrew Mills, and Sierra Armstrong for their assistance with coding and several other undergraduate research assistants of the Kids' Thinking Lab for their assistance with transcriptions. Lastly, we thank the generous support of the schools and daycares that served as testing and recruitment sites, and the participating families who made our work possible.

1.0 Introduction

Young children learn through dynamic social interactions with others (e.g., Rogoff, 1990; Vygotsky, 1978). Individual differences in children's cognitive abilities stem, in part, from variations in the quantity and quality of those interactions, such as the types of conversations that adults and children have. For instance, the amount and diversity of home math activities and math talk, including conversations about math concepts between parents and children, is related to children's math knowledge (e.g., Casey, Lombardi, Thomson, Nguyen, Paz, Theriault, & Dearing, 2018; Ramani, Rowe, Eason, & Leech, 2015; Thompson, Napoli, & Purpura, 2017). Another important aspect of adult-child discussions is adults' use of questions, which encourage children to verbalize their current knowledge and learn new information (e.g., Tompkins, Bengochea, Nicol, & Justice, 2017), and thus, have the potential to impact children's cognitive development.

Although there is a consistent and growing body of literature on the role of questioning in children's language and literacy skills, what remains relatively understudied is whether adults' question use is associated with other cognitive abilities, such as math skills. The current literature suggests that questioning benefits learning because it is an open form of communication that provides children with the opportunity to generate hypotheses and display mastery compared to for example direct instruction, in which they might assume that the communicator's intent is to teach the "whole truth" and leave them little to no room for making inferences (Yu, Landrum, Bonawitz, & Shafto, 2018). Moreover, questions can differ by cognitive complexity (i.e., the extent to which the question demands abstract or conceptual thought) and type (i.e., domain-specificity), which may differentially engage children in challenging conversations and thus relate to children's cognitive development in unique ways. For instance, questions of low- cognitive demand focus on perceptible information (e.g., identifying or recalling) and allow children the opportunity to demonstrate their knowledge and practice skills they already know, while high-cognitive demand questions (e.g., predicting or explaining) invite them to think beyond perceptible information and challenge them to use their emergent language abilities. Adult questioning fosters children's language and problem-solving skills, which are relevant to the development of mathematical thinking (e.g., Purpura & Ganley, 2014). For example, young children with greater language ability may be more capable of processing challenging input (e.g., "Why do you think this happened?" vs. "What color is this?"), which may require complex, multi-step reasoning similar to what they employ when responding to cognitively demanding math-related input (e.g., "How much money do I owe you if each corn is $2?" vs. "How many apples are there?").

Although it is reasonable that questioning in the context of adult-child interactions may be associated with children's math abilities, few studies have examined this relation. In addition, it is not clear whether connections between adult question use and children's cognitive abilities are domain-general or domain-specific. Thus, in this paper, we examine how the frequency and cognitive demand of parents' question use relates to preschool-aged children's math skills. Moreover, given the link between parental math talk and children's math skills, we investigate whether parents' domain-specific math questioning relates to children's math abilities, above and beyond overall questioning. Lastly, we aim to replicate previous findings of the link between parents' question use and children's language skills as a validity check of our measures. It is possible that while domain-general questioning (i.e., all questions) supports both math and language skills, parents' domain-specific math questioning may be uniquely associated with children's math skills given that math questions are more likely than domain-general or total questions to promote mathematical thinking and the domain-specific relations between children's vocabulary and math skills (e.g., Purpura & Reid, 2016).

1.1 Adults' questioning and domain-general contributions to children's math skills

Extant research demonstrates associations between parents' and teachers' question use and children's vocabulary skills (Fletcher, Cross, Tanney, Schneider, & Finch, 2008; Leech, Salo, Rowe, & Cabrera, 2013), as well as improvements in language skills (Blewitt, Rump, Shealy, & Cook, 2009; Leech et al., 2013; Rowe, Leech, & Cabrera, 2017; Strouse, O'Doherty, & Troseth, 2013; van Kleeck, Woude, & Hammett, 2006; Walsh & Rose, 2013), story comprehension (Strouse et al., 2013), story retelling and memory (Daubert, Yu, Grados, Shafto, & Bonawitz, 2020; Kang, Kim, & Pan, 2009), and exploratory and casual learning (Daubert et al., 2020; Yu et al., 2018). In contrast, studies of the associations between domain-general parental questions and children's math achievement are scarce. Reynolds and colleagues (2019) found that fathers' average number of wh-questions during shared book viewing with their children at 6, 24, and 36 months of age were related to children's math achievement in kindergarten. This relation held even after controlling for maternal language input and a variety of demographic variables such as socioeconomic status (SES) and home environment quality. The authors argued that these paternal questions parallel the type of "academic language" that children are exposed to during the first year of formal schooling and thus, they set the foundation for literacy and math achievement in kindergarten (Reynolds et al., 2019). Although this study did not examine child math achievement before formal schooling, we believe that parental questions at the preschool age may also be aligned with the language that researchers use to assess math skills (e.g., in math story problems).

Children who are exposed to a greater quantity of questions may have more experience with the vocabulary and reasoning strategies required to respond to the assessment items. Thus, the frequency with which parents ask questions may be associated with children's math performance.

1.2 The cognitive complexity of questions and potential relations to children's math skills

Beyond the quantity of questions, researchers have examined the unique contributions of the cognitive complexity or demand of adult questions on children's developing skills (Blank, Rose, & Berlin, 1978; Danis, Bernard, & Leproux, 2000; De Temple & Snow, 2000; Rowe, 2004; Zucker, Justice, Piasta, & Kaderavek, 2010). However, researchers vary in how they define levels of complexity (see Walsh & Hodge, 2018 for a review). Common question types include literal versus inferential, perceptual versus conceptual, low versus high demand, contextualized versus decontextualized, immediate versus non-immediate, closed versus open, wh-questions (i.e., who, what, when, where, why), and dialogic questions (e.g., CROWD prompts – completion, recall, open-ended questions, wh-questions, and distancing; Whitehurst, Arnold, Epstein, Angell, Smith, & Fischel, 1994). Despite slight definitional differences, researchers tend to differentiate questions by the amount of abstract, conceptual thought that is required of children to respond. Low-cognitive demand (CD) questions focus on identifying perceptually present, immediate, or concrete information within a text or scenario, while high-CD questions require respondents to go beyond presented information and make connections, summaries, explanations, and predictions. Additionally, wh-questions and dialogic questions can be separated into categories of lower and higher order; dialogic reading moves from questions of low-CD (e.g., "What is that?" or "What food did the animal eat?") to questions of higher-CD (e.g., "What do you think will happen next?"

or “How is this animal different from that one?”). Moving forward, the terms *low-* and *high-CD* questions will be used to refer to these two distinct orders of question complexity.

Exposure to low-CD questions allows children to practice existing skills and demonstrate current knowledge, while high-CD questions challenge them to utilize their emergent language skills and solve problems. Specifically, responses to high-CD questions require children to adopt higher levels of abstract thinking compared to low-CD questions. For instance, asking children about the color of an object, a common low-CD question posed by parents and teachers, generally requires a single word response. Similarly, asking children “how many” objects are present requires counting, which taps a basic number skill. In contrast, asking children about *why* or *how* a process works emphasizes cause-and-effect relations and sequencing or patterning. In the context of play with physical materials, this may encourage children to actively explore the materials, access their memory of the prior steps they took in a process, and practice producing a higher quantity and diversity of talk. Consequently, children become better communicators and are more likely to produce answers of greater complexity or detail than they would when responding to low-CD questions.

Given the impact of parents’ questioning on children’s verbal communication skills, it is possible that parents’ questioning (specifically high-CD questions) may support children’s math skills through their influence on children’s *language* skills, which are also associated with children’s math abilities (e.g., Zhang, Fan, Cheung, Meng, Cai, & Hu, 2017). Language acquisition, specifically vocabulary, involves making connections between words and people, objects, events, or concepts. A similar associative process is involved in the acquisition of the mathematical language that is necessary for understanding and responding to math assessments. For instance, when young children learn the meaning of number words, they develop an understanding that each number word corresponds to one specific quantity. When children transition to learning about relatively complex math concepts, like arithmetic operations, they must understand how operations describe the relations between numbers, e.g., the word "add" refers to combining or summing the quantities of numbers. Parents' questioning may encourage children to engage in the cognitive process of making connections between words and their meanings, which children can apply to their learning of math words and concepts. Parental questions may facilitate young children's acquisition of math- (and non-math) vocabulary, which contributes to children's performance on math assessments, particularly if the tasks have a high language demand (e.g., the assessment questions are orally presented to the child) and contain relatively challenging items (e.g., arithmetic or multi-step problem solving).

Despite the dearth of studies examining adults' questioning and its relation to children's math skills, there are studies that have found that other aspects of adults' verbal input, such as the complexity or abstractness of their speech, impact children's math skills (e.g., Baker, Vernon-Feagans, & The Family Life Project Investigators, 2015; Ribner, Tamis-LeMonda & Liben, 2020). Baker et al. (2015) found that the complexity of fathers' language input, measured by the mean length of their utterances during shared book viewing with their 5-year-old children was associated with children's math skills during the spring of their kindergarten year. This relation held even after controlling for maternal language input, SES, race, parental age, and parental education. One possibility for this relation is that fathers' use of complex utterances promoted children's vocabulary and reasoning skills, which fostered more accurate responses on the math assessment. In other words, children who are accustomed to receiving more complex input engage in deeper reasoning and can better comprehend math word problems. Relatedly, Ribner et al. (2020) studied mothers' distancing language, which requires cognitive abstraction and focuses on information beyond the perceptible or immediate context, paralleling our definition of high-CD input. Mothers were observed sharing a wordless picture book with their 5- to 6-year-old children, and mothers' talk was coded for "distancing utterances." The researchers found that high-CD language mediated the relation between maternal input and children's math and language skills, providing further evidence of the importance of high-CD verbal input for children's academic skill development. Thus, it is possible that parents' high- but not low-CD questions are related to children's math abilities. Aside from supporting children's language abilities, frequent exposure to high-CD questions may contribute to children's problem-solving skills. Children with higher problem-solving skills may have a greater capacity to apply their knowledge and strategies to answering math assessment items that require multiple steps or cover concepts that they are less familiar with. The current study will add to the existing literature on the role of parents' questioning in children's early competencies by examining how low- and high-CD questions are associated with children's *math* skills.

1.3 Adults' language input and domain-specific contributions to children's math skills

Few studies have examined the ways in which math content is conveyed (e.g., through explanations or questions) and little is known about whether domain-specific math *questions* are related to children's math skills. Given the domain-specific contributions of math-related input to children's math skills, which are reviewed below, it is important to consider whether exposure to domain-specific questions, i.e., those addressing math content, relate to children's abilities over and above domain-general questions. Many studies have demonstrated that the quantity of number and spatial talk that adults and children engage in is related to young children's concurrent math abilities (e.g., Elliott, Braham, & Libertus, 2017; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Pruden, Levine, & Huttenlocher, 2011; Ramani et al., 2015) as well as their growth in math (e.g., Casey et al., 2018; Susperreguy & Davis-Kean, 2016). One possibility for these findings is that math-specific input from parents encourages children to focus on and learn about math concepts and/or learn the language necessary to express these concepts. Thus, children with better *math* language skills are likely to perform better on math assessments. Indeed, Purpura and Reid (2016) found that preschool-aged children's number skills were positively related to their math vocabulary above and beyond their general vocabulary. The authors' math language test measured children's understanding of specific words related to quantity and spatial concepts that were considered typical in early mathematics, including "take away", "more", "below", and "nearest". Thus, the association between children's math and language skills may be domain-specific. In the context of parents' question input, parents' *domain-specific* math questions may benefit children's math skills over and above all questioning, given that math questions are more likely than general questions to promote mathematical thinking and learning.

In addition, differences in the content of adult math input, which may vary by cognitive complexity, are uniquely predictive of child math achievement. For instance, Casey et al. (2018) examined the maternal support of numerical concepts, such as counting and arithmetic, in 3-year-old children during play with a cash register, dress-up clothes, and building blocks. The researchers identified numerical concepts along a continuum from least developmentally complex to most complex and the frequency of maternal linguistic support for such concepts were coded: (1) identifying numerals, (2) one-to-one counting, (3) labeling sets, and (4) operations. Children's math achievement at 4.5 and 6-7 years of age were measured using the Applied Problems subtest of the Woodcock-Johnson (WJ) Tests of Achievement (Woodcock & Johnson, 1989), which requires children to analyze and solve mathematical problems presented pictorially and orally. Maternal talk about labeling sets of objects significantly predicted children's later math achievement, even after controlling for other forms of numerical support (i.e., less complex talk about identifying numerals and counting). Similarly, Elliott et al. (2017) found that mothers' talk about numbers greater than 10, not mothers' overall number talk, was associated with 5- to 6-year-old children's formal math ability. These studies suggest that while math talk is important to children's math development, more cognitively demanding input about developmentally complex math concepts (e.g., talk about large numbers or labeling sets) may be more appropriate for or beneficial to children at particular ages or skill levels than low cognitively demanding input (e.g., talk about small numbers or identifying numerals).

Given the nuance regarding how math input may support children's math skills, it is possible that low- and high-CD *domain-specific* math questioning may be differentially associated with children's math skills. For instance, the frequency of parents' low-CD math questions (e.g., "How many…") may relate to children's cardinal number knowledge more strongly than arithmetic or problem-solving skills. In contrast, parents' high-CD math questions (e.g., "How do you know who has more?" or "How many more…") may relate to children's ability to solve complex or multi-step math problems. These questions may encourage children to engage in metacognitive activities, such as reflecting on their strategy use and monitoring their own abilities, which are likely used when children complete math assessments that require them to problem solve.

Two studies have specifically examined adults' domain-specific question use in relation to children's math skills. First, Daubert and Ramani (2019) investigated changes in 3- to 5-year-olds' math skills after playing a linear number board game with an experimenter. Children who interacted with an experimenter who asked math questions (e.g., "How many spaces…?") improved more on subsequent arithmetic and magnitude comparison tasks than children who received math statements (e.g., "You are two spaces ahead") and general positive encouragement (e.g., "Let's hope you get a good spin!"). Second, Uscianowski, Almeda, and Ginsburg (2018) examined parents' use of questions during hypothetical book reading with their children. The researchers presented participants recruited online with visual storybook pages and asked them to indicate questions that they would ask their children to help them learn about characters, numbers, or shapes. Additionally, parents reported their children's abilities in the domains of reading, numbers, and shapes by responding to the question, "Compared to 10 children of the same age as your child, your child would be better than [how many] of them with reading comprehension, such as describing what just happened in the story/numbers, such as counting a group of objects/naming and recognizing different shapes." Parents' high-CD questions about number (e.g., "If two animals walk away, how many animals would we have left?" versus low-CD questions like, "What number do you see?") during hypothetical shared book reading were positively related to their children's counting ability, while no significant associations were found for parents' language about shapes. These studies suggest that exposure to domain-specific math questions may benefit children's acquisition of math knowledge. We expand on the work reviewed above by investigating the domain-specific *and* domain-general relations between parental questioning and children's math skills before formal schooling.

1.4 The current study

Based on the gaps in the extant literature reviewed above, additional work is needed to further delineate the role of questions, both domain-general and domain-specific, for children's math abilities. Although Reynolds et al. (2019) found that fathers' question use related to children's math achievement, it is unknown whether questions that vary in complexity, i.e., low- and high-CD, are differentially associated with children's math skills. This aim is motivated by work showing that high-CD language input is associated with children's math ability (e.g., Ribner et al., 2020). Also, while Uscianowski et al. (2018) found that parents' self-reported question use about number related to counting skill, the researchers relied on mono-method data sources, whereby parents reported on their question use in a hypothetical situation and estimated their child's abilities. Parent reports of their child's math skills are generally inaccurate (e.g., Zippert & Ramani, 2017) and parents' indications of behavior in an online survey may not reflect their actual behaviors when interacting with their children. Finally, though Daubert and Ramani (2019) showed that exposure to domain-specific math questions benefitted children's math abilities in a number board game, whether domain-general questions relate to children's math skills requires further study. Observational studies of parent-child interactions to explore the complexity of parents' questioning and direct assessments of children's math skills have the potential to strengthen the ecological validity of these findings.

The present study addresses these research gaps by exploring the relation between children's math abilities and the cognitive demand (low and high) and type (domain-general and domain-specific) of parent questions with children during three structured observational tasks. We also comparatively examine children's language skills to demonstrate that while domain-general questioning may support both math and language skills, domain-specific math questioning may uniquely relate to math skills. Although domain-specific math questions vary in complexity and have the potential to relate to different domains of children's math skills as reviewed above, the frequency of high-CD math questions in our sample was relatively low. Given that more than half of our parents (n=76) never asked a high-CD domain-specific math question, we summed parents' low- and high-CD math questions for our analyses. Additionally, our analyses control for the total number of parental utterances, child utterances, child age, and socioeconomic status (SES), which relate to our cognitive outcomes of interest (e.g., Cristofaro & Tamis-LeMonda, 2011).

Research Question #1 (RQ1): Does the frequency with which parents ask questions relate to children's math outcomes?

Given recent work on parental questioning and children's math achievement, it is hypothesized that parents' overall questioning is related to children's concurrent math skills.

RQ2: Does the frequency with which parents ask low- and high-CD questions relate to children's math abilities?

Given the results of past work on the complexity of language input and contributions to children's school readiness skills, it is predicted that high-CD questions relate to children's math abilities.

RQ3: Does the frequency with which parents' ask domain-specific math questions relate to children's math skills, above and beyond the total number of questions?

It is predicted that parents' use of domain-specific math questions is positively associated with children's concurrent math skills, over and above parents' total questioning.

RQ4: Does the frequency with which parents ask questions, i.e., total, low- and high-CD, and domain-specific math, relate to children's language skills?

Given the consistent associations between parents' questioning and children's language skills, we hypothesized that parents' total and high-CD questioning would be positively related to children's vocabulary skills. However, it was expected that parents' domain-specific math questioning would be unrelated to children's language skills.

2.0 Method

2.1 Participants

Our data are derived from a study examining how parents promote early learning in four-year-old children. The original sample comprised of 178 parent-child dyads, but 48 families were excluded from the current analyses due to insufficient video data as a result of equipment failures (e.g., camera battery power loss, *n*=2), failure to complete any relevant part of the study (structured observations; child assessments due to experimenter error, child fatigue, or disinterest; parent questionnaire; *n*=44), and the presence of additional family members interacting with the child during the entirety of the structured observations (*n*=2). Additionally, nine dyads were statistically significant outliers in analyses (based on dfbetas, see details below) and were thus excluded. The final sample included in this report consisted of 121 parent-child dyads (*M* child age=53.52, *SD*=3.48 months, Range=48-59.88 months, 54% male children). Families were recruited from a large, mid-Atlantic metropolitan area through the distribution of fliers in the community and in-person contact between the study team and potential participants at preschools and childcare centers. Parents and children were mostly tested in their own homes, but also occasionally in our lab, preschool and daycare centers (see below), and a majority of caregivers were mothers (*n*=114). The race and ethnicity of the caregivers were 82.31% White, 12.31% Black or African American, and 3.85% Asian or Pacific Islander; 1.54% did not report this information. Caregivers reported having less than a bachelor's degree (17.69%), a bachelor's degree (36.15%), or more than a bachelor's degree (46.15%), and they completed an average of 16.35 years of education (*SD*=1.97 years, Range=11-18 years). The mean yearly household income that parents reported was

$107,791.72 (*SD*=$78,303.36, *Median*=$95,000). Welch's t-tests and chi-square tests were used to compare the excluded group to the final sample on the reported demographic variables. The two groups did not significantly differ across these characteristics.

2.2 Measures and procedures

2.2.1 Observation of structured activities

Parents and children were observed engaging in three structured observational tasks: (1) shared picture book viewing, (2) a magnet board puzzle activity, and (3) pretend grocery shopping. Dyads were given approximately five minutes to complete each activity and were given more time (no more than 3 additional minutes) if needed to complete each task. In the book task, parent-child dyads were asked to look at a wordless picture book together that was specifically created by the research team and that had the potential to elicit conversations about numbers and spatial relations. In the puzzle task, dyads were presented with magnet shapes and asked to construct an image of an animal using these shapes based on a model. In the grocery-shopping task, dyads were given a set of developmentally appropriate toys, including pretend food items and a cash register, and instructed to play with the toys as they normally would. A majority of these interactions took place in participants' homes; three dyads engaged in these activities in a quiet room in our lab. Each task was video recorded and transcribed by trained research assistants in our lab.

2.2.2 Transcription coding

For each transcription, occurrences of parent questions were extracted by searching for question marks (*total questions*) and then those questions were coded as either low- or high-CD questions based on previous work (e.g., Blank et al., 1978; Uscianowski et al., 2018; van Kleeck et al., 2006). *Low-CD questions* relate to perceptually present or immediate information and require a response low in cognitive demand, such as labeling, locating, identifying, recalling information, counting, and completing sentences (e.g., "What color is that?"). *High-CD questions* require the respondent to think beyond perceptually present information and a response higher in cognitive demand such as predicting, summarizing, comparing, unifying a sequence of events, problem solving, or explaining (e.g., "Why do you think that happened?"). Few questions occurring in low frequency and unrelated to the task such as, "Can I go to the bathroom?" were coded as "other" and were not included in our analyses. See Table 1 for a full description of question categories and examples from each task. To control for the amount of language input from parents and children, we counted the total number of parental and child utterances in each task. An utterance refers to speech by an individual speaker that is bounded by a speaker transition, a grammatical closure (i.e., a terminal punctuation mark, such as a period or question mark), or a pause of more than two seconds (Pan, Rowe, Spier, & Tamis-LeMonda, 2004).

Further, each question was coded to indicate whether it contained math-related content. Questions were coded as being *domain-specific* if they included at least one word pertaining to a math concept, including identifying numerals, counting, labeling sets, ordinal relations, patterns, and arithmetic, as well as abstract concepts such as dates and time. These categories were chosen based on a combination of coding schemes in the existing math talk literature (e.g., Braham, 2018; Casey et al., 2018; Ramani et al., 2015; Simpson & Linder, 2016). Questions containing number words were not coded as domain-specific if they were not specific to a math *concept*. For instance, the question "How are these *two* pieces different?" is not a domain-specific question because it does not require a math-related response. Also, the question's interpretation would remain the same if the word "two" were omitted. In contrast, the question "Can you point to the number *two*?" is a domain-specific question because it involves identifying a numeral.

Each task was coded for the frequency of different categories of questioning (i.e., cognitive demand and domain-specificity) by two research assistants and at least 20% of the transcriptions per task were double-coded. Every coded transcription was reviewed to compare the exact questions coded and pairs of coders were considered to be in agreement only if the codes *and* particular questions matched. Disagreements were discussed between the pair of coders and the first author, who made the final decision regarding codes. Moreover, 20% of the transcriptions were double-coded for the number of domain-specific math questions and disagreements were discussed between coders and the first author before final decisions were made. To assess the degree of agreement between each pair of coders in identifying the frequency, cognitive demand, and type of parents' questions, kappa statistics (κ) were calculated for categorizing questions as low-CD questions (.88), high-CD questions (.88), and domain-specific math questions (.95). The total number of parental utterances, child utterances, parent questions, parent low-CD questions, parent high-CD questions, and parent domain-specific questions were summed across the three tasks for analyses.

Table 1 Question codes chart

Cognitive demand	Description	*Examples by task*		
		Book	Puzzle	Grocery
Low[+] Questions that relate to perceptually or immediately present information and/or requires a response of low cognitive demand "Look at it" "Talk about it"	Label Locate Identify Describe Recall information Count Complete sentences Follow simple instruction Indicate opinion	How many owls are there?* What are the raccoons doing? These animals are called…?	What color is that big circle? What shape is that? Where is that orange rectangle? How many eyes does the giraffe have?*	What kind of fruit is that? Can you hold the scanner? Can you point to the number two?* Do you like the cookies?
High[^] Questions that require the respondent to think beyond perceptually present information and/or requires a response of higher cognitive demand "Think about it" "Reason"	Predict Summarize Compare Judge Unify a sequence of events Problem solve Justify Explain Demonstrate counterfactual thinking	What patterns do you notice in this book?* What would happen if two owls went home?* Why are there four candles on the cake?*	How are these two shapes different? What shape comes next? How can we fix our mistake? Are there more circles or rectangles?*	How much money do I owe you if each corn is $2?* If I give you a five and you said my stuff costs four, how much money do you give me back?*

[+]Low-CD math questions require identifying numerals or counting
[^]High-CD math questions require comparing quantities or operations
*Indicate domain-specific math questions

2.2.3 Child assessments

Children's number and spatial skills were assessed in one session. A majority of the sessions occurred in a quiet room in participants' homes (*n*=109) immediately after the observational tasks on the same day, at the child's preschool or daycare on a later day (n=9), or in the lab (n=3). Given the relatively low number of children who completed tasks in preschools or the lab, we used Welch's t-tests to compare child assessment scores between sessions that occurred in homes versus the other two locations and found no significant differences.

2.2.3.1 Children's number knowledge

Participants completed the Give-N task (Wynn, 1992) and a counting task designed to assess their number skills. In the Give-N task, children were presented with a set of plastic counters (fish) and two bear puppets, and they were asked to help each bear count by giving it the right number of fish to eat. The puppets were presented individually for six trials each and the range of fish to give each puppet were 1 to 6 in random order. After each trial, the experimenter checked that the child gave the correct number (e.g., "Is that three?"). The dependent measure was the percentage of correct responses. The Give-N task has been found to be highly reliable. Children who are considered a specific N-knower are given the same classification in a titrated version of the task (weighted κ=.87; Marchand & Barner, 2020). In the counting task, children were asked to count out loud to show the experimenter how high they could count. If a child stopped after reaching a certain number, they were prompted to continue (e.g., "What comes next?"). Once the child made one mistake or reached 100, they were stopped. The dependent measure was the highest number that the child could count to without making any mistakes. A composite score of children's number knowledge was computed by averaging the z-scores of the Give-N and counting tasks.

2.2.3.2 Children's spatial skills

Participants completed three assessments which tapped into their knowledge of patterns and geometry. In the patterning assessment (Cronbach's α=.83, Rittle-Johnson, Zippert, & Boice, 2018), children were asked to indicate the next object in an arrangement (2 trials), find the missing object in the middle of a pattern (3 trials), complete a pattern by indicating the next four objects (3 trials), and create the same kind of pattern that was presented to them using different objects (2 trials). No feedback was given and the dependent measure was the percentage of correct responses. In the geometric sensitivity task (Dehaene, Izard, Pica, & Spelke, 2006), children were presented with 12 trials of picture sets, each containing six different images. In each picture set, five out of the six images represented a geometric property (e.g., of distance or angles) that was not present in the last image and children were asked to identify the image that did not fit. Children completed three practice trials with feedback that explained the correct response (e.g., "See, this one is straight, and the others are curved. See, this one is curved, and this one is curved… so this one doesn't go"). No feedback was given in the test trials and the dependent measure was the percentage of correct responses. In the Children's Mental Transformation Task (CMTT; Levine, Huttenlocher, Tayor, & Langrock, 1999), participants were presented with 16 trials, each containing two shapes that undergo a rotation or translation to create one of four picture options. No feedback was given on any item and the dependent measure was the percentage of correct responses. A composite score of children's spatial skills was computed by averaging the z-scores of these three tasks.

2.2.3.3 Standardized math assessment

Children completed the WJ III Applied Problems subtest (r=.93; Woodcock, McGrew, & Mather, 2001), which measured their ability to analyze and solve math problems. The problems became progressively more difficult, with initial items requiring the application of basic number concepts, such as counting, to items requiring arithmetic and knowledge of units, such as currency and temperature. The standardized score on this subtest with an expected mean of 100 and a standard deviation of 15 was z-scored for analyses.

2.2.4 Developmental vocabulary assessment for parents (DVAP)

Children's expressive vocabulary was measured using the DVAP (Libertus, Odic, Feigenson, & Halberda, 2015), which contains 212 nouns, verbs, and adjectives ranging in difficulty (e.g., "girl," "jumping," and "hazardous"). Parents were instructed to indicate which of the listed words they had heard their child say, including words that their child might have used a different part of speech or pronunciation of (e.g., "sleep" or "sreep" instead of "sleeping"). Also, parents were instructed to refrain from asking their child whether they knew the word. Parents completed this questionnaire on a paper copy or electronic format. The words were derived from Form A of the Peabody Picture Vocabulary Test (PPVT-4; Dunn & Dunn, 2007), an experimenter-administered vocabulary assessment. Past work has demonstrated that scores on the DVAP highly correlate with children's PPVT-4 performance, and that the DVAP is a valid indicator of children's expressive vocabulary (Libertus et al., 2015). The dependent measure was the total number of words indicated.

2.2.5 Covariates

Parents completed electronic questionnaires in Qualtrics after the home visit. They provided children's gender and birth date, and age in months was calculated at the first assessment. Parents also reported on background characteristics including educational attainment and household income. Parent education was converted to a continuous variable representing years of completed education (less than a high school diploma or GED=11 years, high school diploma=12 years, some college but no degree=13 years, Associate's degree=14 years, Bachelor's degree=16 years, Graduate degree=18 years). An SES composite was created by averaging the standardized education and income variables.

2.3 Analytic plan

To address RQ1, linear regression analyses were used to determine the relation between the frequency with which parents asked questions and children's math outcomes. Models 1 contained total parent questions, parent utterances, child utterances, child age, and SES as predictors of child-level outcomes; number skills, spatial skills, and standardized math scores were dependent variables in individual models. To address RQ2 and build on previous work by specifying how the cognitive demand of parents' questions may differentially relate to children's skills, similar regression analyses were used to determine the association between the frequency of parents' low- and high-CD questioning and children's math outcomes, after controlling for total parental utterances, child age, child utterances, and SES. Models 2 included the same three child outcomes as the dependent variables. To address RQ3, the same regression analyses were used to determine whether the frequency of parents' domain-specific math questioning relates to children's math outcomes after controlling for parents' total questions, child age, child utterances, and SES (Models 3). Given the low occurrence of high-CD domain-specific math questions across participants (63% of parents asked no high-CD math questions), we used the total number of math questions in Models 3. To answer RQ4 and replicate previous work, we ran the same models for RQs 1 to 3 relating parents' questioning to children's expressive language skills.

We included parent utterances, child age, child utterances, and SES as our covariates of interest because of their potential relations to the amount of parental input that children may receive and our child outcomes. For instance, older children may receive more complex questions and may perform better on the math assessments compared to younger children. Also, children who verbally contribute to conversations with their parents may receive more questions overall than children who speak less. The extent to which children converse may act as a signal to parents that they are capable of or more likely to respond to the input that they receive, which may motivate parents to question more frequently. Finally, past work has shown that there are SES disparities in the amount and diversity of domain-general (e.g., Schwab & Lew-Williams, 2016) and math-specific (e.g., Levine et al., 2010) parental language input. Thus, we included SES as an additional covariate.

Models were first run with all available observations (n=130) and then regression diagnostics were used to identify potentially influential points. Specifically, dfbetas were used to assess the degree to which particular data points influenced the regression estimates of our primary variables of interest (e.g., total parent questions). Outliers with relatively large influence were excluded from our analyses. In some cases, different outliers were identified for different models; we excluded all influential data points to keep a consistent sample across models. A total of nine outliers were excluded (i.e., our final sample consisted of 121 datasets).

3.0 Results

We observed substantial variability in the amount of parents' question use when interacting with their children. Parents produced between 105 and 597 total utterances (*M*=277.71, *SD*=71.01) across the three activities, with an average of 91.82 questions (*SD*=35.66, Range=0-178). Children produced between 54 to 440 total utterances (*M*=189.65159.76*, SD*=57.03) across the three tasks. Parents produced more low- (*M*=78.87, *SD*=30.62) than high-CD (*M*=12.95, *SD*=10.18) questions overall and the majority of the domain-specific math questions occurred in the grocery activity (*M*=4.54, *SD*=4.36). Table 2 displays descriptive statistics of parental language input frequency across all question categories and activities. Table 3 shows descriptive statistics of our child math and language measures and Table 4 displays the correlations between parents' and children's language input and the child outcomes.

Table 2 Descriptive statistics of language input frequency

	Book		Magnet		Grocery		Total	
Input type (*n*=121)	*M* (SD)	Range	*M* (SD)	Range	*M* (SD)	Range	*M* (SD)	Range
Parent utterances	95.69 (35.53)	15-250	93.85 (34.38)	17-250	88.17 (23.55)	17-177	277.71 (71.01)	105-597
Child utterances	53.71 (24.20)	13-201	51.08 (27.02)	5-218	54.97 (20.84)	6-100	159.76 (57.02)	54-440
Parent questions	33.45 (12.75)	0-74	28.73 (15.91)	0-97	24.93 (12.11)	0-89	91.82 (35.66)	0-178
Low-CD	27.50 (12.47)	0-65	20.99 (13.00)	0-95	23.86 (11.25)	0-79	78.87 (30.62)	0-160
High-CD	5.94 (4.83)	0-21	7.73 (6.45)	0-32	1.07 (1.57)	0-10	12.95 (10.18)	0-45
Parent math Qs	3.17 (3.14)	0-13	.54 (.86)	0-4	4.54 (4.36)	0-24	8.24 (5.25)	0-26
Low-CD	2.84 (2.87)	0-11	.43 (.77)	0-4	4.23 (4.03)	0-22	7.52 (4.88)	0-26
High-CD	.32 (.99)	0-6	.11 (.31)	0-1	.29 (.70)	0-4	.714 (1.27)	0-8

Table 3 Descriptive statistics of child outcomes

Variable	Dependent measure	*M* (SD)	Range
Number skills	*z*-scored composite	.04 (.77)	-2.47-1.95
Give-N	Percentage of correct trials	.87 (.20)	.00-1.00
Counting	Highest number counted to	24.46 (23.43)	1-100
Spatial skills	*z*-scored composite	.04 (.79)	-1.49-2.28
Patterning	Percentage of correct trials	.47 (.30)	.00-1.00
Geometric sensitivity	Percentage of correct trials	.39 (.18)	.00-.83
Mental transformation	Percentage of correct trials	.48 (.17)	.12-.94
Standardized math	Normed score with *M*=100, *SD*=15	115.93 (11.20)	71-147
Expressive vocabulary	Number of words indicated out of 212	109.33 (28.33)	36-179
Age	Years	4.46 (.29)	4.00-4.99
Yearly income	Dollars ($)	109,214.24 (77,698.98)	0-425,000

Table 4 Correlations between parental language input and child outcomes

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Parent utterances													
2. Child utterances	.46**												
3. Parent questions	.33***	.01											
4. Low-CD Qs	.34***	.03	.97***										
5. High-CD Qs	.12	-.06	.57***	.35***									
6. Math Qs	.18*	-.02	.47***	.46***	.25*								
7. Low-CD math Qs	.18*	-.01	.46***	.48***	.15	.98***							
8. High-CD math Qs	.03	-.01	.21*	.09	.50***	.45***	.25**						
9. Number skills	-.22*	-.18*	.01	-.03	.14	-.04	-.08	.13					
10. Spatial skills	-.29***	-.22*	-.08	-.13	.12	-.01	-.06	.19*	.64***				
11. Standardized math	-.17	-.09	.01	-.05	.20	-.02	-.08	.23*	.66***	.64***			
12. Vocabulary	.03	-.11	.12	.05	.30***	-.01	-.14	.11	.37***	.29***	.38***		
13. Age	-.04	-.10	-.07	-.10	.06	.02	-.01	.10	.28**	.34***	.03	.12	
14. SES composite	-.06	-.10	.10	.10	0.21*	.01	-.02	.15	.31***	.16	.37***	.26*	-.12

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

3.1 RQ1: Relation between parents' total questions and children's math skills

Regression statistics are shown in Table 5. No significant relations were found between total parent questions and children's math skills. However, our covariates were associated with some of our child outcomes. Total parent utterances negatively related to children's spatial skills (β=-.28, p<.01), child age related to children's number (β=.27, *p*<.01) and spatial skills (β=.34, *p*<.001) respectively, and SES positively related to children's number skills (β=.32, *p*<.001) and standardized math scores (β=.32, *p*<.01) respectively.

Table 5 Linear regression analyses predicting child math outcomes from parents' total questioning

Variable	Number skills		Spatial skills		Standardized math	
	B *(β)*	*SE*	B *(β)*	*SE*	B *(β)*	*SE*
Parental Input						
Total questions	-.00 (-.01)	.00	.00 (.01)	.00	-.00 (-.04)	.00
Total utterances	-.00 (-.19)	.00	-.00** (-.28)	.00	-.00 (-.15)	.00
Child age	.70** (.27)	.23	.92*** (.34)	.23	.07 (.02)	.29
Child utterances	-.00 (-.04)	.00	-.00 (-.06)	.00	-.00 (-.00)	.00
SES	.30*** (.32)	.08	.14 (.14)	.08	.37** (.32)	.10
R^2/Adjusted R^2	.21/.17		.23/.20		.13/.09	
F for R^2	5.96***		6.98***		3.49**	

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

3.2 RQ2: Relation between parents' low- and high-CD questions and children's math skills

Regression statistics are shown in Table 6. Model 2 shows that only the frequency of parents' high-CD question use explained significant variance in children's spatial skills, after controlling for parents' total utterances, child age, child utterances, and SES, $F(6, 114)$=6.98, p<.001, f^2=.30. One standard deviation increase in the frequency of parents' high-CD questions was associated with a .20 standard deviation increase in children's spatial skills. Also, the frequency of parents' high-CD questioning, not low-CD questioning, was significantly related to children's standardized math scores, $F(6,114)=3.94$, $p<.05$, $f^2=.15$, after controlling for parents' total utterances, child age, child utterances, and SES. One standard deviation increase in the frequency of parents' high-CD questions was associated with a .20 standard deviation increase in children's standardized math scores. In contrast, the frequency with which parents asked low- or high-CD questions did not relate to children's number skills.

Table 6 Linear regression analyses predicting child outcomes from parents' low- and high-CD questioning

Variable	Number skills		Spatial skills		Standardized math	
	B (*β*)	*SE*	B (*β*)	*SE*	B (*β*)	*SE*
Parental Input						
Low-CD Qs	-.00 (-.10)	.00	-.00 (-.12)	.00	-.01 (-.17)	.00
High-CD Qs	.01 (.15)	.01	.02* (.20)	.01	.02* (.20)	.01
Total utterances	-.00 (-.18)	.00	-.00** (-.27)	.00	-.00 (-.14)	.00
Child age	.65** (.25)	.23	.84*** (.31)	.22	-.02 (-.00)	.29
Child utterances	-.00 (-.03)	.00	-.00 (-.04)	.00	.00 (.01)	.00
SES	.28** (.30)	.08	.11 (.11)	.08	.34** (.29)	.10
R^2/Adjusted R^2	.23/.19		.27/.23		.17/.13	
F for R^2	5.54***		6.98***		3.94**	

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

3.3 RQ3: Relation between parents' domain-specific math questions and children's math skills

Regression statistics are shown in Table 7. The frequency of parents' domain-specific math questioning did not relate to children's number skills, spatial skills, standardized math scores, after controlling for total parent questions, child utterances, child age, and SES. Additionally, we ran exploratory analyses with parents' low- and high-CD domain-specific math questioning and found no significant associations which are not presented here.

Table 7 Linear regression analyses predicting child math outcomes from parents' domain-specific math questioning

Variable	Number skills		Spatial skills		Standardized math	
	B *(β)*	*SE*	B *(β)*	*SE*	B *(β)*	*SE*
Parental Input						
Math Qs	-.01 (-.04)	.01	-.01 (-.08)	.01	-.01 (-.07)	.02
Total Qs	.00 (.02)	.00	.00 (.05)	.00	-.00 (-.01)	.00
Total utterances	-.00 (-.19)	.00	-.00** (-.29)	.00	-.00 (-.15)	.00
Child age	.71** (.27)	.23	.94*** (.35)	.23	.10 (.03)	.29
Child utterances	-.00 (-.04)	.00	-.00 (-.06)	.00	-.00 (-.01)	.00
SES	.30*** (.32)	.08	.14 (.14)	.08	.37** (.32)	.10
R^2/Adjusted R^2	.21/.17		.24/.20		.14/.10	
F for R^2	4.96***		5.90***		2.99**	

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

3.4 RQ4: Relation between parents' questions and children's language skills

Regression statistics are shown in Table 8. While the frequency of parents' total questions did not relate to children's expressive vocabulary, parents' high-CD questioning was significantly related to children's vocabulary, $F(6,114)=3.34$, $p<.01$, $f^2=.12$, after controlling for parents' total utterances, child age, child utterances, and SES. One standard deviation increase in the frequency of parents' high-CD questions was associated with a .30 standard deviation increase in children's expressive vocabulary. No significant relations were found with parents' low-CD questions or domain-specific math questions.

Table 8 Linear regression analyses predicting child language skills from parents' questioning

Variable	Expressive vocabulary					
	RQ1		RQ2		RQ3	
	B *(β)*	*SE*	B *(β)*	*SE*	B *(β)*	*SE*
Parental Input						
Total questions	.07 (.09)	.08	--	--	.13 (.16)	.09
Low-CD Qs	--	--	-.09 (-.10)	.09	--	--
High-CD Qs	--	--	.83 (.30)***	.27	--	--
Math Qs	--	--	--	--	-.71 (-.13)	.56
Total utterances	.02 (.06)	.04	.03 (.07)	.04	.02 (.05)	.04
Child and Family Characteristics						
Child age	11.21(.12)	8.84	7.72 (.08)	8.62	12.41 (.13)	8.86
Child utterances	-.04 (-.08)	.05	-.03 (-.06)	.05	-.04 (-.09)	.05
SES	8.14 (.24)*	3.16	6.78 (.20)*	3.08	8.11 (.24)	3.15
R^2/Adjusted R^2	.09/.05		.15/.11		.10/.05	
F for R^2	2.17		3.43***		2.08	

Note: RQ1 addressed the relation between parents' total questions and children's outcomes. RQ2 examined the relation between parents' low- and high-CD questions and children's skills. RQ3 addressed the associations between parents' domain-specific math questions and children's outcomes. **p*<.05, ***p*<.01, ****p*<.001

4.0 Discussion

The present study explored the relation between the cognitive demand and type of questions parents use with children in dyadic interactions and children's math and language skills. Specifically, we were interested in the complexity of parents' questioning (low- and high-CD) and the relation to children's math abilities, because few studies have examined this. Although the frequency with which parents asked questions was not associated with any of our child outcomes, the cognitive demand of their questions differentially related to children's math abilities. This points to the importance of analyzing parents' questioning beyond the frequency of total questions. Specifically, the quantity of parents' high-CD question use was related to children's spatial skills, standardized math scores, and expressive vocabulary even when controlling for the total number of parental utterances, child age, child utterances, and SES. These results so far suggest that the findings in which parents' questioning supports children's math and language skills (e.g., Reynolds et al., 2019) may be partially driven by high-CD questions. These questions promote thinking beyond perceptible information and engage problem-solving, summarizing, and explaining, and they may benefit from or be shaped by children's math skills. Surprisingly, the frequency of parents' domain-specific math questioning was not associated with children's math skills after controlling for parents' total questioning, parent utterances, child utterances, child age, and SES. Potential explanations for this finding are discussed below. Overall, our findings highlight the importance of considering the cognitive demand or complexity of parents' questioning as it relates to child outcomes, not just the *quantity* of input.

Our results are consistent with previous work demonstrating that the frequency with which parents ask questions, specifically high-CD questions, is related to children's vocabulary skills (e.g., Zucker et al., 2010). Here, we extend previous findings by showing that the quantity of parents' high-CD questioning is associated with children's spatial skills and standardized math, even after controlling for child age, child utterances, and SES, suggesting that domain-general questioning may support specific cognitive abilities. Although our measures are concurrent and we cannot establish causal relations between our variables, we offer possible explanations for the directionality of our findings. One possible explanation is that parents' use of high-CD questions in the observational tasks accurately reflects the type of input that they expose their children to in everyday situations. High-CD questions may promote abstract thinking and complex language use which are involved in spatial and mathematical reasoning. Thus, children more familiar with high-CD questions perform better on assessments that involve such questions. For instance, when children are asked a high-CD question such as, "How can we fix our mistake?" or "What shape comes next?" in the puzzle task, they might engage in several processing steps (e.g., study the current state of the puzzle, compare it to the model image, and observe what is missing, etc.) before responding, which may parallel some of the strategies used to solve problems in our spatial assessments or standardized math test. Further, parents' high-CD questioning may be associated with children's expressive vocabulary because high-CD input typically exposes children to more diverse and abstract talk. This encourages them to provide a response of greater complexity (e.g., an explanation), allowing them the opportunity to practice using less frequent, more challenging words and sentences. In contrast, the quantity of parents' high-CD questions did not relate to children's number skills. Since children were asked low-CD questions in the number skills assessments (e.g., "Can you show me how high you can count?"), it is likely that the mental processes children engage in when responding to these questions do not parallel the strategies that they use in the number skills tasks.

Another possibility is that parents' question use reflects their sensitivity to their children's math and language skills. Parents may be matching the complexity of their questioning to their perception of their child's abilities, similar to the way some adults adapt to the cognitive level of the child they are interacting with during joint book reading (Danis et al., 2000). Indeed, our language measure directly assessed parents' perception of their child's vocabulary knowledge by asking them to indicate the total number of words that they had heard their child say on a given word list. Thus, it is possible that parents who evaluated their children as having high vocabulary skills felt that it was appropriate to ask more high-CD questions. Relatedly, parents may be adjusting their questioning based on their child's prompts or responses to their questions. It is possible that parents continued to pose more high-CD questions throughout the interaction because their child adequately responded to them; this could have signaled to the parent that it was appropriate and useful to do so. Additionally, the quantity of parents' low-CD questions did not relate to any child math and language outcomes. All parents in our sample asked low-CD questions, with a majority of them asking more low- than high-CD questions. This may reflect parents' beliefs about the type of age-appropriate language input for their children, regardless of ability level.

Further, although domain-general questioning relates to children's spatial skills, standardized math scores, and language skills, parents' domain-specific math questioning did not relate to children's math or language skills. While this pattern of findings is inconsistent with past research on the domain-specific association between parental math talk and child math ability (e.g., Casey et al., 2018), we do not interpret this to mean that math questions may not be beneficial to children's math development and learning. One possibility for these null findings is that only questions about specific math concepts (e.g., arithmetic, comparison) may be related to children's math abilities at the age tested here. We only captured questions related to numbers in the current study and omitted potentially important domain-specific math questions (e.g., questions related to quantifiers or spatial math concepts). Additionally, it may take time for domain-specific math questions to have an impact on children's math skills and we were unable to capture this with our concurrent measures. Finally, it is possible that the importance of domain-specific math questions is only apparent when contrasted with the total amount of math talk, not the total number of questions or utterances. To explore this possibility, future work should carefully distinguish between domain-specific math questions and domain-specific math statements.

One strength of the current study is that we controlled for potentially confounding parent and child factors in our models. Controlling for the total number of parental utterances allowed us to separate the quantity of talk, which is a well-known source of variation in children's language outcomes (e.g., Cristofaro & Tamis-LeMonda, 2011), from the frequency of parents' question use in predicting children's math and language skills. Controlling for the quantity of child utterances allowed us to adjust for the possibility that children who frequently talk during interactions with their parents are asked more questions. Also, adjusting for child age isolated the influence of age on parental input and child outcomes. Older children may receive more language input and they may have higher math and language abilities. Lastly, controlling for SES accounted for the possibility that high-SES parents would provide more language input to their children (e.g., Schwab & Lew-Williams, 2016).

4.1 Limitations and future directions

Despite our best efforts, we acknowledge several limitations of our study. First, the data were collected concurrently and based on observations. Thus, we can only speculate on the direction of the relations in our findings. Future work will explore how parents' question use relates to changes in children's abilities over time. As noted above, it is possible that parental language input takes time to impact children's skills. Additionally, experimental studies are needed to determine whether the cognitive demand and domain-specificity of parents' questioning is causally related to children's math and language skills. For example, dyadic interactions could be observed in which some parents are randomly selected to engage in specific types of questioning and children's abilities can be assessed before and after these interactions.

Moreover, the observational tasks were highly structured and may not actually reflect the everyday interactions that children experience. Although the tasks were selected to provide different opportunities for rich conversations between parents and children, we do not know how familiar they were with the task materials or how atypical it might have been for some dyads to engage in these activities. These tasks may be capturing how parents and children interact under ideal situations, e.g., if they had access to these materials, time, and little to no distractions. Also, our study only considered one caregiver, primarily mothers. Research shows that fathers pose more wh-questions than mothers (Rowe et al., 2004) and fathers' question use is positively associated with children's vocabulary skills (Leech et al., 2013), suggesting that mothers and fathers may influence children's learning at different levels and in unique ways. Future research examining dyadic interactions in more naturalistic settings with multiple caregivers would increase the ecological validity of these findings.

Also, past research has shown that there are SES differences in the amount and diversity of domain-general language input (e.g., Schwab & Lew-Williams, 2016), math-specific parental input (e.g., Levine et al., 2010), and children's early math skills (e.g., Anders, Rossbach, Weinert, Ebert, Kuger, Lehrl, & von Maurice, 2012). In our sample, SES was significantly related to children's number skills and standardized math scores in all models, and parent high-CD questions were positively correlated with SES (r=.21, p<.05). This suggests that the associations between parents' high-CD questions and children's math skills may be partially driven by high-SES parents. Future work should examine dyadic interactions within a more diverse range of families as well as variability within SES groups.

Although the inclusion of parent- and child-level covariates helped us isolate the relation between parental questioning and children's math and language abilities, several potential casual variables were either omitted from our models due to our small sample size or not measured. Future work should consider other important aspects of children's behavior in dyadic interactions, such as child temperament or responsiveness. Such factors may affect how parents choose to talk to their children during the interactions, resulting in more or less talk related to behavioral or emotional management compared to the type of input that we coded here.

Further, we examined the independent contributions of parents' low- and high-CD questioning to children's math and language outcomes, finding null associations between low-CD questioning and our child outcomes. Future work should investigate how parents use a *combination* of low- and high-CD input and whether this relates to children's math abilities. Past work has demonstrated that exposure to a mix of low- and high-CD questions from adults is associated with children's language abilities (e.g., Blewitt et al., 2009), which may explain why parents' low-CD questioning alone did not relate to children's skills in our study. Low-CD questioning is an important initial step in scaffolding, a technique that can be approximated by speakers moving from low- to high-CD questions (e.g., dialogic questioning) and is related to improvements in young children's language abilities (Blewitt et al., 2009; De Temple & Snow, 2000; Leech et al., 2013; Rowe, 2004; van Kleeck et al., 2006). For example, Blewitt et al. (2009) found that scaffolding effectively helps 3-year-olds learn novel words during joint book reading with a parent, beyond receiving strictly low- or high-CD input. A structured combination of low- and high-CD questioning supports young children's learning by guiding them through a process of demonstrating their current knowledge and appropriately challenging them to utilize their emergent language skills and solve problems (e.g., Danis et al., 2000). Many of the parents in our sample asked both types of questions and it is possible that some were attempting to scaffold. Future work should investigate how parents structure their low- and high-CD input and the relation to children's abilities.

Additionally, our definition of domain-specific math questions was limited to language input involving numbers and did not include talk about spatial concepts, such as shapes, dimensions, and locations, or approximate numerical information such as quantifiers. As a result, math questions were relatively infrequent in the puzzle task compared to the grocery task (see Table 2 for descriptive statistics on parental input by question category and task). Future work should examine the contribution of parents' *quantifier* and *spatial* questions to children's math and language abilities, which we expect to show positive relations given the associations between parental spatial talk and children's spatial language and skills documented in prior work (e.g., Pruden et al., 2011) and the role of language and number processing in comprehending quantifiers and numerical information (e.g., Dolscheid & Penke, 2018; Shikhare, Heim, Klien, Huber, & Willmes, 2015). Also, future research should attempt to tease apart the specific math skills that are associated with parents' domain-general and domain-specific questions. While we included measures of children's number and spatial skills, these were composite scores derived from averaging performance in tasks that measured different aspects of larger constructs. For instance, the spatial skills composite reflected children's knowledge of patterns, geometric concepts, and rotations and translations. Given that these individual assessments measure specific math knowledge and parents may be sensitive to some skills (e.g., patterning) more than others (e.g., mental rotations), examining how they relate to parents' questioning would allow us to better specify the mechanisms of these relations.

Lastly, future work should examine other aspects of dyadic interactions, such as the child's contribution to the conversation. It is possible that parents' language input, particularly the quantity of high-CD questions, influences the complexity of children's responses which affects subsequent parental input. Children's high-CD verbal responses may relate to their spatial skills and expressive vocabulary through the opportunity to practice using more abstract and complex words or phrases. Future sequential analyses of parent-child interactions are warranted.

Moreover, parent-child interactions involve dynamic communicative input, including the use of gestures, which is not captured in our current coding scheme. Many of the parents in our sample used speech and gesture to guide the interactions and past work suggests that gestures, such as pointing and iconic gestures, contribute to children's vocabulary development (e.g., Rohlfing, 2011; Rohlfing, Grimminger, & Nachtigaller, 2013). Pointing and iconic gestures, which refer to hand or arm movements that convey information about objects, actions, or events, can reinforce or supplement ideas presented verbally and strengthen the connection between words and their definitions. The importance of gesture to children's developing math skills is evidenced in studies examining its contribution to children's spatial reasoning (e.g., Ehrlich, Levine, & Goldin-

Meadow, 2006). Future work should examine how parents complement their language input with gestural input to support children's emerging math and language skills.

4.2 Conclusion

Parental questioning has the potential to support children's math and language development in different ways. We found that the quantity of parents' high-cognitive demand questions was associated with children's spatial abilities, standardized math scores, and vocabulary skills, above and beyond the total number of parental utterances, child age, child utterances, and SES. Our results provide detailed insight into the contribution of parental questions to children's math abilities, adding to an area of work that is dominated by research on the role of questioning in language development. This work has broader implications for the creation of interventions or resources to encourage and help parents engage in educationally beneficial learning opportunities with their preschool-aged children.

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