

**Math Talk by Mothers, Fathers, and Toddlers:  
Differences across Materials and Associations with Children's Math  
Understanding**

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## **Math Talk by Mothers, Fathers, and Toddlers: Differences across Materials and Associations with Children's Math Understanding**

Abstract words are difficult to learn. Unlike concrete nouns, which tend to refer to objects with distinct perceptual features (Landau et al., 1988), abstract words, such as adjectives and prepositions, refer to dissimilar kinds of referents and functions. Unsurprisingly, children learn abstract words at later ages than they do concrete nouns and words for social routines such as “hi” and “bye” (Bates et al., 1994; Frank et al., 2021). Words that refer to spatial concepts (e.g., the toy under the table) and number concepts (e.g., three little pigs)—“math talk”— may be particularly challenging to learn given their abstract nature. Nonetheless, children’s early math vocabulary lays a critical foundation for emergent math cognition and has cascading effects on later math achievement (e.g., Duncan et al., 2006; Geary et al., 2013; Jordan et al., 2009; Miller et al., 1995; Nguyen et al., 2016; Pruden et al., 2010; Purpura & Reid, 2016; Toll & Van Luit, 2014; Watts et al., 2014). Thus, illuminating factors that relate to children’s early exposure to and understanding of math language has theoretical and practical significance.

Grounded in a developmental systems perspective that learning results from bidirectional influences between the individual and the environment (e.g., Gottlieb, 1991), we conceptualize children’s learning of math words as embedded in context. Children influence their environments as they engage with people, objects, and places and they elicit prompt and meaningful input from caregivers that in turn supports learning (e.g., Golinkoff et al., 2015; Masek, McMillan et al., 2021; Schatz et al., 2022, Tamis-LeMonda & Masek, 2023). Furthermore, reciprocal infant-caregiver interactions are situated in a physical environment (including available materials) that may further influence language use (e.g., Hoff, 2006; Soderstrom & Wittebolle, 2013). For example, mothers use more noun types than verb types when engaging in book-reading with their toddler and more verb types than noun types when engaging in toy-play (Tardif et al., 1999).

We examined how play materials relate to parents’ and toddlers’ use of particular types of math talk and tested associations between parents’ math talk and toddlers’ production and understanding of math words. We focused on toddlerhood because children begin to grow in their use of abstract language at this time, yet most research on math talk targets preschoolers (e.g., Daubert et al., 2018; Eason & Ramani, 2020; Ferrara et al., 2011; Thippaana et al., 2020). Additionally, we observed mothers and fathers from English- and Spanish-speaking families, thus expanding beyond the relatively homogenous samples of most developmental research. Including a diverse sample of parents allowed us to test the robustness of findings across parent sex (mothers and fathers) and language (English and Spanish).

### **Types of Math Talk**

In line with research on the home math environment of young children (e.g., Eason et al., 2022; Hart et al., 2016; Zippert & Rittle-Johnson, 2020), we define “math talk” as a range of words and phrases that convey key concepts about number and space. Numeracy talk includes words for numbers (e.g., “one”, “two”) and ordinal relations (e.g., “first”, “second”) (Levine et al., 2011; Mix et al., 2012; Ramani et al., 2015; Daubert et al., 2018). Spatial talk includes words for shapes (e.g., “square”, “triangle”), spatial properties (e.g., “side”, “corner”), spatial relations (e.g., “above”, “below”, “here”, “there”), and spatial orientation (e.g., “backward”, “diagonal”) (e.g., Pruden et al., 2010). Magnitude words convey both quantitative and spatial concepts (e.g., “big number” or “big circle”) and are thus critical types of math talk (e.g., Cannon et al., 2007).

Early exposure to and production of math talk is crucial to study for theoretical and practical reasons. Theoretically, words for abstract numerical and spatial concepts are difficult to learn. Referents for math talk can be relatively difficult to infer, particularly for toddlers. “Two” can refer to two eyes, two jumps, or two more minutes. Similarly, words for shapes such as

“circle”—commonly assumed to be concrete—can refer to the shape of the moon, the path of an object, or a feature of the environment such as a cul-de-sac. Math words also encode relational information that can be perceptually varied and relative: the street is “above” the subway but also “below” the sky, and a dog is “big” compared to a mouse but “little” compared to an elephant. To successfully learn such words, children must extract the invariant features of such dissimilar referents.

Practically, children’s understanding of math concepts relates to their early numeracy and spatial skills (Levine et al., 2011; Miller et al., 1995; Pruden et al., 2011; Purpura & Reid, 2016; Toll & Van Luit, 2014), which in turn have downstream consequences for later math performance (Duncan et al., 2006; Geary et al., 2013; Jordan et al., 2009; Nguyen et al., 2016; Watts et al., 2014) and even career outcomes (Parsons & Bynner, 2005; Ritchie & Bates, 2013).

### **Early Learning of Math Talk**

Most children begin to use words for math concepts in the second year of life. Of the 39 math words included on the American English MacArthur-Bates Communicative Development Inventory (MB-CDI), 9 are produced by more than half of 24-month-olds and 25 are produced by more than half of 30-month-olds, the oldest age for which the MB-CDI is valid (Frank et al., 2021). Development in children’s math vocabularies is also reflected in their learning of novel words. Whereas 3-year-olds consistently succeed in mapping novel spatial relations represented by nonce words (i.e., invented words that match the phonology of the language being tested, such as “*acorp* my box”), 2-year-olds are highly variable in their success (Fisher et al., 2006; Landau & Stecker, 1990).

In the context of these developmental trends in math vocabulary, children vary widely in their math skills at preschool entry (Elliot & Bachman, 2018; Harvey & Miller, 2017; Ramani et al., 2015; Silver & Libertus, 2022). Exposure to math talk at young ages—particularly during interactions with parents—likely contribute to early-emerging differences.

### ***Parental Language Input***

The speech to which children are exposed guides the words that they understand and produce. Children are similar to their parents in total talkativeness (e.g., Hart & Risley, 1995), lexical diversity (e.g., Rowe 2012), and the syntactic structure of their utterances (e.g., Huttenlocher et al., 2010). Indeed, between 86% and 98% of words in 3-year-olds’ vocabularies come directly from the words that they hear from their parents (Hart & Risley, 1995).

Similarly, math talk of parents relates to the math talk of their children. Parent numeracy talk correlates with 3- to 5-year-olds’ numeracy talk during play with a number puzzle (Daubert et al., 2018) and with 2- to 4-year-olds’ numeracy talk during pretend play (Eason et al., 2021). Similarly, parents’ spatial talk is associated with 4-year-olds’ spatial talk during block play (Polinsky et al., 2017). In toddlerhood, the scant existing work on math talk shows that parents’ math talk predicts children’s use of math talk concurrently and over time. In one study, mothers’ overall math talk (summing across numeracy and spatial words/phrases) during home activities related to the math talk of their 12- to 26-month-old infants. Moreover, toddlers’ math talk mostly occurred within seconds of mothers’ use of math talk (Mendelsohn et al., 2022), suggesting that parents support their toddlers’ use of math talk in the moment. Longitudinal studies of math talk found that parents’ cumulative spatial talk to their 14- to 46-month-olds at home related to children’s cumulative spatial talk and performance on spatial task assessments at 54 months old (Pruden et al., 2011), and parents’ cumulative numeracy talk to their 14- to 30-month-olds at home related to children’s understanding of number terms at 46 months old (Gunderson & Levine, 2011; Levine et al., 2010). However, research on parent math talk predominantly targets mothers of preschoolers, and so the types of math talk that fathers use, and their association with toddlers’ math talk remains an open question.

### ***Materials and Math Talk***

Language interactions occur in an environmental context that includes places, spaces, and available materials. Mothers of 1- to 2-year-olds label their toddlers' actions (West et al., 2022) and the objects that toddlers touch (Suarez-Rivera et al., 2022), and the content of mothers' language varies with activities (e.g., mealtime, grooming; Tamis-LeMonda et al. 2019). Accordingly, available materials may likewise affect parents' math talk to toddlers.

Studies of preschoolers indicate that play materials relate to parents' use of math talk. Parents are more likely to use math talk with 4-year-olds during play with puzzles or building toys than during sports activities or arts and crafts (Thippana et al., 2020). Furthermore, caregivers use different *types* of math talk when engaging with different types of materials (Daubert et al., 2018; Eason et al., 2022; Ferrara et al., 2011; Thippana et al., 2020; Verdine et al., 2019), such as spatial locations while playing with blocks and numbers while playing with board games.

However, whether play materials affect parents' use of math talk to toddlers, who are just learning to use number and spatial words themselves, remains unexamined. Specificity of math words by task may characterize parents' math-related input to toddlers, as seen with children of older ages. Alternatively, parents may simplify their language by using concrete nouns in short utterances, rather than introducing abstract math terms. Indeed, parents almost double their use of novel words per utterance and increase the length of their utterances by 50% between children's ages of 2 and 5 years (Kunert et al., 2011).

### **Current Study**

Three research questions framed our study. First, does the math talk of mothers, fathers, and toddlers during play interactions vary by materials? We quantified numeracy, spatial, and magnitude talk across four sets of play materials (a picture book, a grocery shopping set, a magnet board, and a shape sorter). Second, does the math talk of mothers and fathers relate to toddlers' use of math talk during interactions? Third, does the math talk of mothers, fathers, and toddlers relate to toddlers' understanding of words for spatial relations, shapes, and numbers in independent assessments?

Given the lack of research on parent and child math talk during the toddler period, we considered two possibilities for parents' use of math words/phrases. Parents' math talk with toddlers may change with the affordances of materials—a specificity hypothesis—mirroring findings with parents of 3- to 5-year-olds (e.g., Daubert et al., 2018; Ferrara et al., 2011; Silver et al., 2024; Thippana et al., 2020; Verdine et al., 2019). Alternatively, parents may largely use imprecise math talk such as deictics (“here” and “there”), rather than using math terms/phrases such as “underneath”, “to the side”, and so on, and be generally unlikely to use abstract math words with toddlers. If so, parents' math talk will be non-specific to materials and infrequent. We were uncertain about whether mothers versus fathers, and parents from English- versus Spanish-speaking households would differ in their use of math talk. However, we expected high variability among parents, across sex and spoken language, in line with the high variability seen for parents' language input generally and math talk specifically in prior studies (e.g., Levine et al., 2010; Mendelsohn et al., 2022; Pruden et al., 2011).

For toddlers, we expected infrequent math talk and fewer individual differences among toddlers in the use of math words/phrases compared to parents (e.g., Frank et al., 2021; Mendelsohn et al., 2022). In terms of toddler math words in the presence of different materials, we again considered two possibilities. Toddlers may show specificity in math talk, particularly if their parents' math talk changes with play materials and scaffolds toddlers' use of math talk in the moment. Alternatively, toddlers may use whatever words they know regardless of materials; if so, toddlers' math talk may not change in type or frequency across different materials.

Regardless of how much math talk parents and toddlers produce *on average*, variation in math talk among parents should relate to variation in math talk among toddlers. For

associations with assessments of toddlers' math understanding, we considered several possibilities. One possibility is that both parent and toddler math talk relate to math understanding, even if parents use more math talk than do their toddlers; this would align with prior work on the math understanding of 3- to 4-year-olds (e.g., Levine et al., 2010; Pruden et al., 2011). A second possibility is that parent math talk (but not toddler math talk) relates to toddlers' understanding of math concepts, given that receptive vocabulary surpasses expressive vocabulary at this age. That is, toddlers may understand more math words than they produce. Finally, parents' and toddlers' use of math words during interactions may not predict toddlers' performance on assessments—which test for a variety of words about number, shapes, and spatial relations—if parents and toddlers use a narrower set of math words than are included in assessments.

## Method

### Participants

Participants were 58 toddlers ( $M_{age} = 30.4$  months at the first visit, range: 24.3 - 36.4, and  $M_{age} = 31.2$  months at the second visit, range: 24.9 - 36.5; 30 female) and their biological parents. Mothers and fathers completed separate visits. Two toddlers participated with just their father; 14 participated with just their mother; and 42 participated with both mother and father for a total of 100 parents. Between 97 and 98 parents played with each of the four sets of materials, resulting in 391 observations of caregiver-toddler interactions for analyses.

Families were recruited across three Northeastern cities in the United States through community agencies, pediatrician offices, local hospitals and clinics, and institutional participant databases. All procedures were approved by the Institutional Review Boards at the participating institutions. Inclusionary criteria were: 1) child born at term with no diagnosed health complications or disabilities, 2) two biological parents interested in participating, both of whom were over 18 years at the time of the child's birth, 3) parents speaking primarily English and/or Spanish with their child and identifying as either Latine or non-Latine White (see Table 1 for demographic information for participants). Parents were told that researchers were interested in understanding toddlers' development and observing how toddlers play with their parents; they were not told that math talk was the focus of the study.

### Procedures Overview

Each home visit began with video recordings of parent and toddler during four play interactions, followed by assessments of toddlers' understanding of words for shapes and spatial relations (Visit 1) or numbers (Visit 2). Assessments were divided across the two visits to minimize burden and maximize toddler interest. Across the 42 families who completed both visits, 20 families had the mother-child visit first and 22 families had the father-child visit first. Ordering of parent visit did not relate to the time between visits.<sup>1</sup>

### Parent-Child Interactions

Toddlers engaged separately with their mothers and fathers with a picture book (3 minutes), shape sorter (3 minutes), magnet board (5 minutes), and a toy grocery shopping set (5 minutes)—materials that provided unique opportunities to talk about number, space, and magnitude. All dyads played with the materials in the same order (picture book, shape sorter, magnet board, grocery set). A foam mat was placed on the floor to define participants' location for videorecording. Parents were instructed, *“Can you and [child] have a seat here on the mat? I am going to give you some toys to share together. We sanitized all of the toys before this visit.*

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<sup>1</sup> Several families only had the first home visit due to a halt in data collection because of the coronavirus pandemic.

*After I put the toys out, I will just be over here completing paperwork and you should try to keep [child] engaged."* Parent-child dyads were given one set of toys at a time. Each toy was removed before placing the next one on the mat. The researcher refrained from engaging with the toddler or parent during play with each toy.

### **Picture Book**

Two wordless, custom-made books were used (counterbalanced across parent so that toddlers read a different book with their mother and their father), each containing 24 pages of pictures of everyday objects such as foods and animals, in sets ranging from one to 10 (e.g., a page with two horses and a page with six apples). The book also had five pages each marked with a numeral one to five with a picture of the corresponding number of items (e.g., numeral two and two bananas). The researchers placed the picture book (open to the first page), on the mat and instructed the parent, *"Please share this book with [child]. After 3 minutes we will stop you so you can start the next activity. Have fun!"*

### **Shape Sorter**

The shape sorter was a wooden cube with holes of various shapes on four sides accompanied by brightly colored blocks of the same shapes. The shape sorter included 12 shapes: star, triangle, square, rectangle, clover, diamond, parallelogram, oval, octagon, hexagon, pentagon, and trapezoid. The same shape sorter was used for both visits. The researcher placed the shape sorter on the mat with all blocks outside and next to the sorter. The researcher instructed the parent, *"Please share these toys with [child]. After 3 minutes we will stop you so you can start the next activity. Have fun!"*

### **Magnet Board**

The magnet board consisted of 25 magnetic shapes, a magnetic white board, and a laminated picture of an image that could be made with the shapes. The shapes contained circles, half circles, arcs, triangles, squares, and rectangles of different colors and sizes. The picture card showed an image of either a person or rocket ship (images were counterbalanced across parent so that toddlers constructed a different image with their mother and their father). The researcher laid out the magnet board with the magnetic shapes on one side of the board and the picture card above the board. The researcher told the parent, *"We'd like you and [child] to try to make the image in this picture from these magnet pieces. After 5 minutes, we will stop you so you can start playing the next activity. Have fun!"*

### **Grocery Shopping Set**

The grocery shopping set consisted of a cash register, play money (two one-dollar bills; two five-dollar bills; two ten-dollar bills), a shopping basket, and a set of play food. Play food items were in groups that ranged from one (e.g., one apple) to 10 (e.g., 10 potato chips). Two sets of toy foods were used (counterbalanced across parent so that toddlers played with different foods sets with their mother and their father). A few food items were constant across sets (e.g., two ice-cream cones), but most differed. When foods differed between sets, the number of different groups of food items, the number of each food item in a group, and the overall number of food items remained constant (e.g., 10 potato chips and one strawberry in one set and 10 French fries and one apple in the other). The researcher placed the grocery shopping set on the mat with the cash register in the middle, the food to one side, and the basket to the other side, and instructed the parent, *"Please share these toys with [child]. After 5 minutes we will stop you so you can start the next activity. Have fun!"*

### **Transcription of Interactions**

Parent-child interactions were transcribed by trained research assistants using Datavyu (<https://datavyu.org>), an open-source, computerized coding tool. Speech was segmented at the

utterance level. A second researcher verified transcriptions and disagreements were settled through discussion.

### ***Development of Math Talk Coding Manuals***

A manual for math talk was developed for this project by building on prior coding manuals (e.g., Cannon et al., 2007; Levine et al., 2010) and supplementing with new math words/phrases that we identified through an iterative process of watching videos and adding to the manual. Specifically, we generated our list of math words/phrases by sampling across videos of English- and Spanish-speaking parents, mother-toddler and father-toddler interactions, older and younger toddlers, and the full range of play materials. Researchers in our labs (three doctoral students and three research staff, two of whom were bilingual in English and Spanish) first translated all math words from prior coding manuals into Spanish, adding additional words that did not have direct translations from English (e.g., “allí” and “allá” for “there”). Then, based on the video recordings, they incorporated any additional words that parents or toddlers used to express mathematical concepts. The process of updating word lists continued until no additional math words were identified. The final list of words contained 681 English math words and 1150 Spanish math words (the Spanish-language list was longer to accommodate varied word endings). The coding manuals for English and Spanish math words are openly shared at [\[link redacted for blind review.\]](#)

### ***Coding Math Talk***

Math words/phrases were coded in Datavyu from transcripts along with viewing of videos. Ruby scripts searched for the identified math words and flagged the utterances in which a math word occurred in the Datavyu transcription. Trained research assistants then classified each math word into one of 12 categories from the coding manual: numbers (e.g., “one” “two”), ordinals (e.g., “first”, “last”), singular referents (e.g., “this one”, “that one”), functions (e.g., “count”, “add”), shapes (e.g., “square”, “circle”), magnitudes (e.g., “big”, “little”), spatial locations/directions (e.g., “on”, “below”), spatial orientations (e.g., “backwards”, “upside down”), spatial features/properties (e.g., “side”, “line”), spatial deictics (e.g., “here”, “there”), time (e.g., “now”, “later”) or as a false alarm (i.e., a math word that was used in a non-math context, such as “come on” or “behind schedule”). False alarms, singular referents, and time words were not analyzed further. A second trained research assistant double coded 20% of the interactions. Percent agreement was high between coders ( $M = 93.8\%$ , range: 62.2% - 100.0%<sup>2</sup>).

After initial coding, math categories were grouped into three broad types of talk: (1) Numeracy—words that refer to numbers and numerical order (e.g., “one”, “two”, “three”, “first”, “second”, “before”, “next”), (2) Spatial—words that describe geometric shapes and features, spatial properties, spatial position, or spatial relations (e.g., “circle”, “square”, “side”, “in”, “on”, “here”, “there”), and (3) Magnitude—words that refer to a size or amount (excluding number words; e.g., “big”, “little”, “more”, “all”, “piece”). Math words per minute was calculated (consistent with Pruden et al., 2011) for each of the three types of math talk for mothers, fathers, and toddlers to control for the varying lengths of time that parents and toddlers played with each set of materials.

### ***Assessments of Toddler Math Understanding***

Researchers assessed toddlers’ comprehension of math concepts using three tasks: Point-to-Shape, Point-to-Spatial-Relation, and Point-to-X. All tasks were coded based on whether the toddler identified the correct picture on each trial (correct = 1, incorrect = 0). A second trained research assistant double-coded 20% of the trials. Inter-coder reliability was high

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<sup>2</sup> The unusual low reliability of 62% was due to one coder noting “cone” (in ice-cream cone) as a shape and the other coder noting “cone” as a false alarm (our rule was to call this a false alarm).

(Point-to-Shape  $\kappa = .93$ ; Point-to-Spatial-Relation  $\kappa = .77$ ; Point-to-X  $\kappa = .96$ ). Internal consistency, as measured by Cronbach's alpha, was acceptable (Point-to-Shape  $\alpha = .78$ ; Point-to-Spatial-Relation  $\alpha = .63$ ; Point-to-X  $\alpha = .68$ ), given that toddlers are just beginning to learn these math words, hence knowledge of one word is not necessarily indicative of knowledge of another word. For all tasks, the final score was the proportion of correct trials. We prorated toddlers' performance by number of trials completed (e.g., if a child was administered 8 trials, and succeeded at 4, the child received a score of .50). For all tasks, possible scores ranged from 0 (no trials correct) to 1 (all trials correct).

### ***Point-to-Shape Task***

Toddlers' understanding of shape names was assessed during the first home visit using the Point-to-Shape task. The researcher presented the toddler with a set of 10 cards, one at a time, each depicting two geometric shapes. The researcher said to the toddler, *"Let's look at these pictures! In this game, I'll tell you the name of a shape and you show me which one it is."* The researcher then asked the toddler to identify a given shape. For example, toddlers would be presented with one card that had an image of a triangle on the left and diamond on the right and the researcher asked, *"Where's the triangle?"*. The shape names tested: "heart", "star", "diamond", "triangle", "rectangle", "circle", "square", and "oval" (note: "triangle" was assessed three times using different classifications of triangles). Of the 58 toddlers who had a first home visit, 55 children had data for the task.

### ***Point-to-Spatial-Relation Task***

Toddlers' understanding of spatial relation terms was assessed during the first home visit using the Point-to-Spatial-Relation task. The researcher presented the toddler with a set of 7 cards, one by one, each depicting two images of a tiger and one or two cups. The pictures on cards were the same except for the tiger's location in relation to the cup. The researcher said to the toddler, *"Let's play another game! The tiger is hiding. I'm going to tell you where he is hiding, and I want you to show him to me."* The researcher then asked the toddler to find the picture that demonstrated a given spatial relation. For example, the card would show a picture of the tiger next to the cup on the left and a picture of the tiger on top of the cup on the right and the researcher would ask, *"Where's the tiger on top of the cup?"*. The spatial relations tested were: "on top of", "under", "between", "in front of", "behind", "in", and "next to". Of the 58 toddlers who had a first home visit, 52 children had data for the task.

### ***Point-to-X Task***

Toddlers' understanding of number words one to 10 was assessed during the second home visit using the Point-to-X task. Two non-numeric practice trials were given prior to the start of the task. After the practice trials, the researcher presented the toddler with 12 pairs of cards (one pair at a time), with the paired cards spaced 12 inches apart. The two cards depicted the same objects but differed in the quantity of objects. The researcher said, *"Let's look at pictures!"* then asked the toddler to select the picture that showed a given quantity of objects. For example, toddlers would be presented with a picture of a plate with three cookies and a picture of a plate with one cookie and the researcher would ask, *"Which has one cookie?"* If the toddler did not respond, the researcher would give another prompt, such as *"Does this plate have one, or does this plate have one?"*, making a circular gesture towards each picture. Number words tested were "one", "two", "three", "four", "five", "seven", and "ten" (numbers one through five were each assessed twice). Of the 42 toddlers who had a second home visit, 37 children had data for the task; an additional 6 toddlers were excluded due to answering incorrectly on both practice trials.

## Analysis Plan

We calculated descriptive statistics on all variables. Most were normally distributed, with a few exceptions. Specific types of parent math talk (numeracy, spatial, and magnitude), broken down by play material, were right-skewed. We thus log-transformed tokens per minute. Additionally, specific types of toddler math talk, broken down by material, were infrequent, and therefore dichotomized (i.e., coded as 0—if the child did not use the type of math talk—or 1—if child used the type of math talk). Transformed variables were used in analyses of types of math talk for each set of materials.

To test the associations between type of play material and type of math talk used by parents and toddlers (Research Question #1), we ran one linear mixed model for parents and one logistic regression for toddlers. All models included four fixed effects: (1) type of play material (picture book, shape sorter, grocery shopping set, and magnet board); (2) math talk (numeracy, spatial, and magnitude); (3) parent's dominant language (determined by whether the parent used more English or Spanish during the interaction); and (4) parent sex (mother or father). The first two fixed effects directly tested the research question, and the second two fixed effects tested the robustness of findings across sample demographics. Models included two random effects, one for individual parent (to account for the repeated measures within each individual parent-child dyad) and one for individual child (to account for shared variance between parents of the same child in the parent model and repeated measures across parents in the toddler model). Models included demographic controls: parent age, parent education (in years), toddler age, and toddler gender. We further controlled for parents' total number of utterances in the model that included parent math talk, given that overall utterances related to math talk,  $r(95) = .63$ ,  $p < .001$ . Similarly, we controlled for toddler total number of utterances in the model that included toddler math talk, which likewise related to toddler math talk,  $r(56) = .63$ ,  $p < .001$ .

For each model, the primary aim was to test the interaction between play materials and type of math talk. We report an omnibus F-statistic for interactions predicting parents' math talk. For the toddler math talk model, the logistic nature of the data did not permit calculation of an omnibus F-test for interactions. We thus present the range of z-statistics for the overall significance of the interaction. A significant interaction between play materials and type of math talk, for the parent or the child model, would provide support for a specificity hypothesis, whereas a nonsignificant interaction would suggest no differences in type of math talk by materials.

We tested associations between parent math talk and toddler math talk during interactions (Research Question #2) separately for mother-child and father-child interactions using Pearson correlations. To do so, we averaged mother (or father) and toddler (with mother or with father) total math words per minute across the four sets of play materials. We tested associations between parent and toddler use of math talk and assessments of toddlers' math understanding (Research Question #3), using Pearson correlations. To do so, we averaged the math talk of mothers and fathers across play materials. Similarly, we created an average of toddlers' math talk across play materials and across mother and father. In cases where only one parent participated, math talk was based on the single visit. We tested correlations for Research Questions #2 and #3 without and then with controls (parent age, parent education, parent dominant language, toddler age, toddler gender, total utterances).

## Results

Parents and toddlers varied widely in their math talk. Math talk of individual parents ranged from 0 to 21.81 total math words per minute for a given set of materials. In the context of variability in parents' math talk, all but one parent used at least some math talk with each set of toys (one father used no math talk with the picture book) and all but one parent used

words/phrases from every category of math talk (one mother used no magnitudes). Mothers' and fathers' overall math talk was stable across play materials, although stability differed across types of math talk (Table 1 lower diagonal). Toddler math talk ranged from 0 to 18.98 total math words per minute, although the toddler who used 18.98 math words per minute was an outlier. All but one toddler produced at least some math talk in at least one interaction, 67% of toddlers used words/phrases from every category of math talk. Like parents, toddlers' total math talk was stable across play materials, although stability differed across types of math talk (Table 1 upper diagonal). Aggregating across all interactions, parents and toddlers together produced 181 unique math words in English and 180 unique math words in Spanish.

### Parent Math Talk: Associations with Demographics

In general, the amount of parent math talk did not differ by parent sex (mother, father) and dominant language (English, Spanish), as indicated by an absence of main effects on overall math talk when aggregating across types of math talk and play materials,  $F(1, 47.02) = 0.84$ ,  $p = .363$ , and  $F(1, 64.64) = 0.78$ ,  $p = .381$ , respectively. However, parent dominant language modified certain associations between type of math talk and materials, as reflected in an omnibus significant 3-way interaction  $F(6, 953.68) = 4.24$ ,  $p < .001$ . Therefore, we report findings by parent dominant language.

### Parent Math Talk Differs by Play Materials

Parents generally used more spatial talk than numeracy talk, and used more numeracy talk than magnitudes,  $F(2, 953.68) = 307.84$ ,  $p < .001$ . Parents used the most math talk when interacting with the magnet board compared with the other materials,  $F(3, 975.17) = 11.37$ ,  $p < .001$ . In support of a specificity hypothesis, the types of math talk parents directed to their toddlers (i.e., numeracy, spatial, and magnitude) differed across play materials,  $F(6, 953.68) = 135.75$ ,  $p < .001$  (Table 2, Figure 1).

Numeracy. English- and Spanish-dominant parents used more numeracy words per minute during play with the picture book and the grocery shopping set than with the shape sorter and the magnet board. English-dominant parents also used more numeracy talk during play with the picture book than with the grocery shopping set. Numbers between one and 10 were among the most frequent numeracy words during play with the picture book and the grocery shopping set for both English- and Spanish-dominant parents. During the shape sorter and the magnet board, parents mostly used the numbers “one/uno” and “two/dos” (Figure 2).

Spatial. English- and Spanish-dominant parents used more spatial words per minute during play with the magnet board and the shape sorter than with picture book and the grocery shopping set. English- and Spanish-dominant parents also used more spatial talk with the grocery shopping set than with the picture book. Parents used a variety of spatial words when interacting with the shape sorter and the magnet board including deictics, shape names, spatial properties, orientations, locations, and precise spatial relations. While playing with the grocery shopping set and interacting with the picture book, parents mostly used deictics (Figure 3).

Magnitude. Specificity was seen for magnitudes for English-dominant, but not Spanish-dominant parents. English-dominant parents used more magnitude words per minute when playing with the grocery shopping set than with the picture book and shape sorter. They also used more magnitude words when playing with the magnet board than with the picture book. In contrast, Spanish-dominant parents used similar amounts of magnitude words across tasks. Nonetheless, English-speaking and Spanish-speaking parents were similar in the magnitude words that they used across the four sets of materials (Figure 2).

### Toddler Math Talk: Associations with Demographics

Toddlers were equally likely to use math talk with mothers and fathers,  $z = 0.44$ ,  $p = .661$ , and did not differ in their likelihood of using math talk by parents' dominant language,  $z = -0.73$ ,  $p = .469$ . The only demographic factor that related to toddler math talk was toddlers' age,  $z = 2.07$ ,  $p = .039$ .

### Toddler Math Talk Differs by Play Materials

Toddlers were more likely to use numeracy than other forms of math talk, range:  $z = 0.36$ ,  $p = .720$  to  $z = 4.35$ ,  $p < .001$ , and they used the most math talk with the grocery shopping set than with other materials, range:  $z = 1.04$ ,  $p = .299$  to  $z = 6.59$ ,  $p < .001$ . Furthermore, toddlers' types of math talk differed by play materials, supporting a specificity hypothesis and mirroring results for parents (range:  $z = 1.98$ ,  $p = .047$  to  $z = 6.77$ ,  $p < .001$ ; Table 3 and Figure 3). Notably, an absence of 3-way interactions—when crossing math language type and play materials with (a) parent sex and (b) parent dominant language—indicated that patterns of toddler math talk across play materials did not differ for interactions with mother and father or for English- and Spanish-speaking dyads.

Numeracy. More toddlers (both English- and Spanish-dominant) used numeracy talk with the picture book and the grocery shopping set than with the shape sorter and the magnet board. Like their parents, toddlers frequently used small count numbers between one and 10 during play with the grocery shopping set and the picture book and mostly used the numbers “one/uno(a)” and “two/dos” during play with the magnet board and the shape sorter (Figure 4).

Spatial. More toddlers (both English- and Spanish-dominant) used spatial talk while playing with the shape sorter and the magnet board than with the grocery shopping set and the picture book. More toddlers also used spatial talk with the grocery shopping set than the picture book. With both the magnet board and the shape sorter, toddlers, like their parents, used a variety of spatial terms. With the grocery shopping set, toddlers were most likely to use deictics and precise spatial relations. During play with the picture book, the few spatial words that toddlers produced were almost entirely deictics (Figure 4).

Magnitude. Few toddlers used words to express magnitude. Nonetheless, toddlers were more likely to use magnitudes when playing with the grocery shopping set and the magnet board than with the picture book. Toddlers were also more likely to use magnitudes with the magnet board than the shape sorter. Toddlers used a variety of magnitude words with few differences across play materials (Figure 4).

### Parent Math Talk Relates to Toddler Math Talk

Overall, associations between mothers' and fathers' math talk and toddlers' math talk were moderate to large in effect size and statistically significant when controlling for toddler age, toddler gender, parent education, parent dominant language, parent age, parent total utterances, and child total utterances,  $pr(47) = .55$ ,  $p < .001$  and  $pr(32) = .55$ ,  $p < .001$ , respectively,  $r(54) = .42$ ,  $p = .001$  and  $r(39) = .27$ ,  $p = .093$ , respectively, without controls (Figure 5). The association between mother and toddler talk did not differ statistically from that between father and toddler math talk,  $z = 0.80$ ,  $p = .424$ .

### Parent Math Talk Relates to Toddler Math Understanding

Toddlers varied in their performance on the three math tasks: Point-to-Shape task ( $M = 0.57$ ,  $SD = 0.31$ ), Point-to-Spatial-Relations task ( $M = 0.54$ ,  $SD = 0.33$ ), and Point-to-X task ( $M = 0.48$ ,  $SD = 0.27$ ) (See Figure 6). Most children scored higher than chance on the Point-to-Shape and Point-to-Spatial-Relations tasks (51% and 62%, respectively), but not on the Point-

to-X task (39%)<sup>3</sup>, although average performance did not differ from chance for any of the tasks (all  $p$ 's > .05). Child age was associated with toddlers' performance on the Point-to-Shape task ( $r(53) = 0.35$ ,  $p = .009$ ) and the Point-to-Spatial-Relations task ( $r(50) = 0.38$ ,  $p = .006$ ), but not on the Point-to-X task ( $r(29) = 0.15$ ,  $p = .406$ ).

Associations between parent overall math talk and child spatial understanding were moderate (see Figure 7A) even when controlling for demographics: Point-to-Shape task,  $pr(46) = .48$ ,  $p < .001$ , the Point-to-Spatial-Relations task,  $pr(43) = .41$ ,  $p = .006$ . The effect size for the Point-to-X task was small and nonsignificant (see Figure 7A), even with controls,  $pr(22) = 0.28$ ,  $p = .183$ .

When examining breakdowns of parent type of math talk, parents' use of numeracy and spatial talk generally showed near-zero to small effect sizes (all nonsignificant) to measures of child math understanding. In contrast, parents' use of magnitudes showed moderate effect sizes in relation to measures of math understanding, although not all associations reached significance when demographic controls were included (see Table 4). This suggests that parents' comparisons between discrete and continuous quantities and dimensions may broadly support toddlers' understanding of math concepts.

### **Toddler Math Talk Relates to Toddler Math Understanding**

Toddlers' overall math talk showed moderate to large effect sizes to toddlers' spatial understanding (see Figure 7B), even when controlling for demographics: Point-to-Shape task,  $pr(46) = 0.35$ ,  $p = .016$  and Point-to-Spatial-Relation task,  $pr(43) = 0.42$ ,  $p = .003$ . The effect size for the Point-to-X task was also moderate, but nonsignificant (see Figure 7B), even with controls  $pr(22) = 0.29$ ,  $p = .170$ .

## **Discussion**

Language learning is embedded in a social and physical context. Here we extend the principle of embedded learning to the domain of math language. By manipulating the objects of play, we show that specific materials offer unique opportunities for toddlers to hear and produce specific words. Moreover, patterns of specificity cut across mothers, fathers, and toddlers from Spanish- and English-speaking families, with both parents' and toddlers' use of math words relating to toddlers' understanding of specific math concepts.

### **Variation in Math Talk is Large**

Huge variation characterized parents' math talk to toddlers. Whereas some parents produced dozens of math words with each set of play materials, others produced none (e.g., when interacting with the shape sorter, one parent named colors, but did not use any spatial talk, including shape names). Likewise, toddlers varied in their use of math words and understanding of math concepts. Although toddlers' math talk was generally infrequent, some toddlers used several math words and others used none. Similarly, some toddlers correctly identified all shapes, spatial relations, and numbers in assessments, others performed at chance, and others did not answer prompts. Large individual differences before age 3 years indicate potential for downstream consequences for school readiness.

### **Math Talk is Specific to Materials**

In line with a specificity hypothesis, the materials of play shaped the words that parents and toddlers used. Mothers, fathers, and toddlers talked more about numbers when playing with the grocery shopping set and the picture book—both of which contained or showed sets of

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<sup>3</sup> Trials in which children did not select one of the two images presented (e.g., responded "I don't know" or simply named the object in the picture), received scores of 0, which brings the average down below chance. However, we chose to include all available data for full transparency and to avoid selective reporting of performance.

objects—than with the shape sorter or the magnet board. Conversely, parents and toddlers talked more about shapes and spatial relations when playing with the shape sorter and the magnet board—both of which involved orienting and placing different shaped blocks or tiles to achieve a goal—than with the grocery shopping set or the picture book. Thus, during play with the magnet board and shape sorter, parents and toddlers referred to a variety of spatial concepts, not solely shapes. The effects of play materials on math talk spotlights context-dependency with toddlers, who are just beginning to learn words for math concepts, in line with research with older children (Daubert et al., 2018; Ferrara et al., 2011; Thippana et al., 2020). Findings also add to the literature on how object interactions affect caregiver language input. Mothers name the objects of infant play (Suarez-Rivera et al., 2022) and the actions their infants produce (West et al., 2022). Here, play materials influenced parents' talk about abstract concepts such as space and number.

### **Parent Math Talk Relates to Toddlers' Math Talk and Understanding of Math Language**

Mothers' and fathers' math talk related to toddlers' math talk in both English-speaking and Spanish-speaking dyads, mirroring research on the talk of English-speaking parents with preschoolers (e.g., Thippana et al., 2020). Moreover, associations maintained even when controlling for overall amount of talk. The real-time connections between parents' and toddlers' math talk suggest that parents' input may support toddlers' use of these relatively difficult words (see also Mendelsohn et al., 2022) or that parents may adapt their use of math talk to the words their toddlers use themselves.

Furthermore, parents' and toddlers' math talk related to toddlers' performance on assessments of math understanding, building on associations documented for parent and toddler spatial talk (Pruden et al., 2011) and between parent numeracy talk and children's math performance (Levine et al., 2010; Thippana et al., 2020). Effect sizes were moderate to large for associations to toddlers' understanding of spatial words, but not numeracy words. Parents' use of words for magnitudes showed the strongest association to toddlers' math assessments. Words for magnitudes apply to both numerical and spatial concepts and are frequently used during everyday activities (Mendelsohn et al., 2022). Indeed, magnitudes are early learned math words (Frank et al., 2021), such as when toddlers request "more" crackers or the "big" cookie. Thus, magnitudes may scaffold toddlers' learning of words for other math concepts such as number, shapes, and spatial relations.

### **Similarities and Differences in Mothers and Fathers from English- and Spanish-speaking Families**

Our study of a diverse sample of families enabled us to test replicability of findings across mothers and fathers from English-speaking and Spanish-speaking families. Mothers and fathers in our study did not differ in overall amount of math talk, even though the well-documented advantage of males in STEM fields might suggest that fathers would use more math talk than mothers (e.g., Ceci et al., 2014). Similarly, the effect of play materials on math talk generalized to English-speaking and Spanish-speaking parents. Such findings confirm the robustness of the effect of play materials on lexical aspects of language.

Moreover, a focus on dyads from different language communities highlights the unique ways that different languages encode math-related concepts. For example, size can be encoded in the endings of the word in Spanish, by adding "-ito" or "-ita" for something small or "-ón" or "-ona" for something large. However, the same endings can also be used to convey a sense of cuteness, in the case of "-ito" and "-ita", or greatness in the sense of "-ón" or "-ona". Exploration of transcripts revealed that Spanish-speaking parents used the ending "-ito" to convey size at least some of the time. One parent used the phrase, "Esto es cuadrado" ("this is the little square" to tell the child which shape to get) and another used the phrase, "Le damos una vueltecita" ("we give it a little turn" to instruct the toddler to turn a shape a small amount).

English-speaking parents used similar phrases, but with the corresponding spatial word “little” (e.g., “little square” and “turn it a little bit”). The study of how different languages encode math concepts may yield unique insights into trajectories of children’s learning (Choi & Bowerman, 1991; Dowker et al., 2008; Masek, Ramirez et al., 2021; Melzi et al., 2022).

### **Directions for Future Research**

Our manipulation of materials in parent-child structured tasks leaves open questions about mothers’ and fathers’ everyday use of math talk in the ecologically valid home setting. What types of math talk do parents and toddlers produce while eating a snack, getting dressed, or playing with arts and crafts, and so on? Notably, associations between parent math talk and child math performance differ by setting—with stronger associations for talk during unstructured activities at home and weaker associations for talk during structured tasks in the lab (Silver et al., 2024; Thippana et al., 2020).

Relatedly, future research should examine the multi-modal behavioral cues (e.g., touch, gesture, language, attention, movement) that parents produce when using math talk. During the earliest years of math talk learning, toddlers likely rely on social cues to help them connect abstract terms to their meaning. What kinds of cues are available to them? Perhaps parents use object-oriented actions or gestures to accompany math talk, stacking blocks one-by-one as they count them or placing a *triangle* block *on top* of a *rectangle*. Or, perhaps at home, parents engage in larger body movements, such as lifting the child up while saying “up”—the kind of social cues to math talk that are unlikely to be observed during structured, largely stationary play tasks.

Measuring toddlers’ understanding of math concepts is challenging because few assessments exist for children under the age of three years old. Here, we focused on toddlers’ understanding of math words given that receptive vocabulary precedes production. However, several other numerical and spatial skills may relate to later math performance, including cardinality, verbal counting, understanding of approximate quantities, spatial assembly, mental rotation, and navigation. Future work should examine how early math talk relates to this broader suite of numeracy and spatial skills.

### **Conclusion**

Toddlers are faced with the challenging task of mapping abstract words about number, space, and magnitude to their real-world referents. Language input and the materials available for play provide rich opportunities for learning. As toddlers interact with objects of different shapes, quantities, and magnitudes, their exposure to and use of math talk reinforce learning of critical math concepts. Variations in math-related talk are already evident in toddlerhood, relate concurrently to toddlers’ math talk and understanding, and potentially spill over to later math achievement. The early emergence of individual differences and the potential of certain play materials to support specific aspects of math cognition have implications for early education and programming.

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**Table 1. Demographic information for parents.**

|                             | English Dominant<br>Mothers<br>(n = 21) | Fathers<br>(n = 21) | Spanish Dominant<br>Mothers<br>(n = 35) | Fathers<br>(n = 21) | Test of Differences<br>Language | Parent   |
|-----------------------------|-----------------------------------------|---------------------|-----------------------------------------|---------------------|---------------------------------|----------|
|                             | <i>n</i>                                | <i>n</i>            | <i>n</i>                                | <i>n</i>            | $\chi^2$                        | $\chi^2$ |
| Race/Ethnicity              |                                         |                     |                                         |                     | 67.27 ***                       | 0.24     |
| Latine                      | 3                                       | 4                   | 34                                      | 20                  |                                 |          |
| White, non-Latine           | 18                                      | 17                  | 0                                       | 0                   |                                 |          |
| Did not report              | 0                                       | 0                   | 1                                       | 1                   |                                 |          |
| Language Use                |                                         |                     |                                         |                     | 73.98 ***                       | 2.37     |
| English                     | 12                                      | 11                  | 1                                       | 1                   |                                 |          |
| Spanish                     | 0                                       | 1                   | 32                                      | 14                  |                                 |          |
| English & Spanish           | 3                                       | 3                   | 0                                       | 1                   |                                 |          |
| English & Other             | 4                                       | 4                   | 0                                       | 0                   |                                 |          |
| Spanish & Other             | 0                                       | 0                   | 1                                       | 1                   |                                 |          |
| Did not report              | 2                                       | 2                   | 1                                       | 4                   |                                 |          |
| Education                   |                                         |                     |                                         |                     | 31.61 ***                       | 4.57     |
| Less than High School       | 3                                       | 1                   | 15                                      | 13                  |                                 |          |
| High School Diploma         | 0                                       | 0                   | 6                                       | 2                   |                                 |          |
| Some College                | 8                                       | 6                   | 6                                       | 1                   |                                 |          |
| Bachelor's Degree           | 8                                       | 9                   | 6                                       | 3                   |                                 |          |
| Master's Degree or more     | 1                                       | 5                   | 1                                       | 1                   |                                 |          |
| Did not report              | 1                                       | 0                   | 1                                       | 1                   |                                 |          |
|                             | <i>M (SD)</i>                           | <i>M (SD)</i>       | <i>M (SD)</i>                           | <i>M (SD)</i>       | <i>t</i>                        | <i>t</i> |
| Parent Age in Years         | 32.5 (4.5)                              | 33.4 (4.1)          | 33.2 (5.1)                              | 38.4 (6.3)          | 1.86                            | 2.06 *   |
| Child Age Visit 1 in Months | 31.3 (4.5)                              | 30.7 (3.3)          | 29.9 (3.8)                              | 30.4 (3.5)          | 0.85                            | 0.26     |
| Child Age Visit 2 in Months | 31.0 (3.1)                              | 31.8 (4.2)          | 31.1 (3.3)                              | 30.1 (3.4)          | 0.71                            | 0.21     |

*Note.* Parent dominant language is determined by parents' math language use while interacting with their toddlers. Tests of differences for parent race/ethnicity, parent language use, and parent education report Chi-squares. Tests of differences for parent and child age report t-statistics. \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ .

**Table 1. Correlations for math talk between each task for toddlers (above the diagonal) and parents (below the diagonal).**

| Total Math Talk      |              |              |              |                      |
|----------------------|--------------|--------------|--------------|----------------------|
|                      | Picture Book | Shape Sorter | Magnet Board | Grocery Shopping Set |
| Picture Book         | --           | 0.41*        | 0.49*        | 0.49*                |
| Shape Sorter         | 0.29*        | --           | 0.66*        | 0.47*                |
| Magnet Board         | 0.15         | 0.23*        | --           | 0.37*                |
| Grocery Shopping Set | 0.34*        | 0.46*        | 0.20         | --                   |
| Numeracy             |              |              |              |                      |
|                      | Picture Book | Shape Sorter | Magnet Board | Grocery Shopping Set |
| Picture Book         | --           | 0.17         | 0.26         | 0.32*                |
| Shape Sorter         | -0.04        | --           | 0.42*        | -0.16                |
| Magnet Board         | 0.02         | 0.24*        | --           | -0.10                |
| Grocery Shopping Set | 0.31*        | 0.06         | 0.01         | --                   |
| Spatial              |              |              |              |                      |
|                      | Picture Book | Shape Sorter | Magnet Board | Grocery Shopping Set |
| Picture Book         | --           | 0.03         | 0.09         | 0.11                 |
| Shape Sorter         | 0.20         | --           | 0.64*        | 0.39*                |
| Magnet Board         | 0.19         | 0.19         | --           | 0.43*                |
| Grocery Shopping Set | 0.11         | 0.39*        | 0.29*        | --                   |
| Magnitude            |              |              |              |                      |
|                      | Picture Book | Shape Sorter | Magnet Board | Grocery Shopping Set |
| Picture Book         | --           | 0.36*        | 0.41*        | 0.54*                |
| Shape Sorter         | .34*         | --           | 0.32*        | 0.32*                |
| Magnet Board         | .34*         | .24*         | --           | 0.49*                |
| Grocery Shopping Set | .33*         | .31*         | .41*         | --                   |

*Note.* Toddler correlations, to the right and above the diagonal, are calculated based on a dense rank of an average of tokens per minute of math talk used with mothers and fathers (for toddlers who had two visits). Parent correlations, to the left and below the diagonal, are calculated on dense rank tokens per minute.

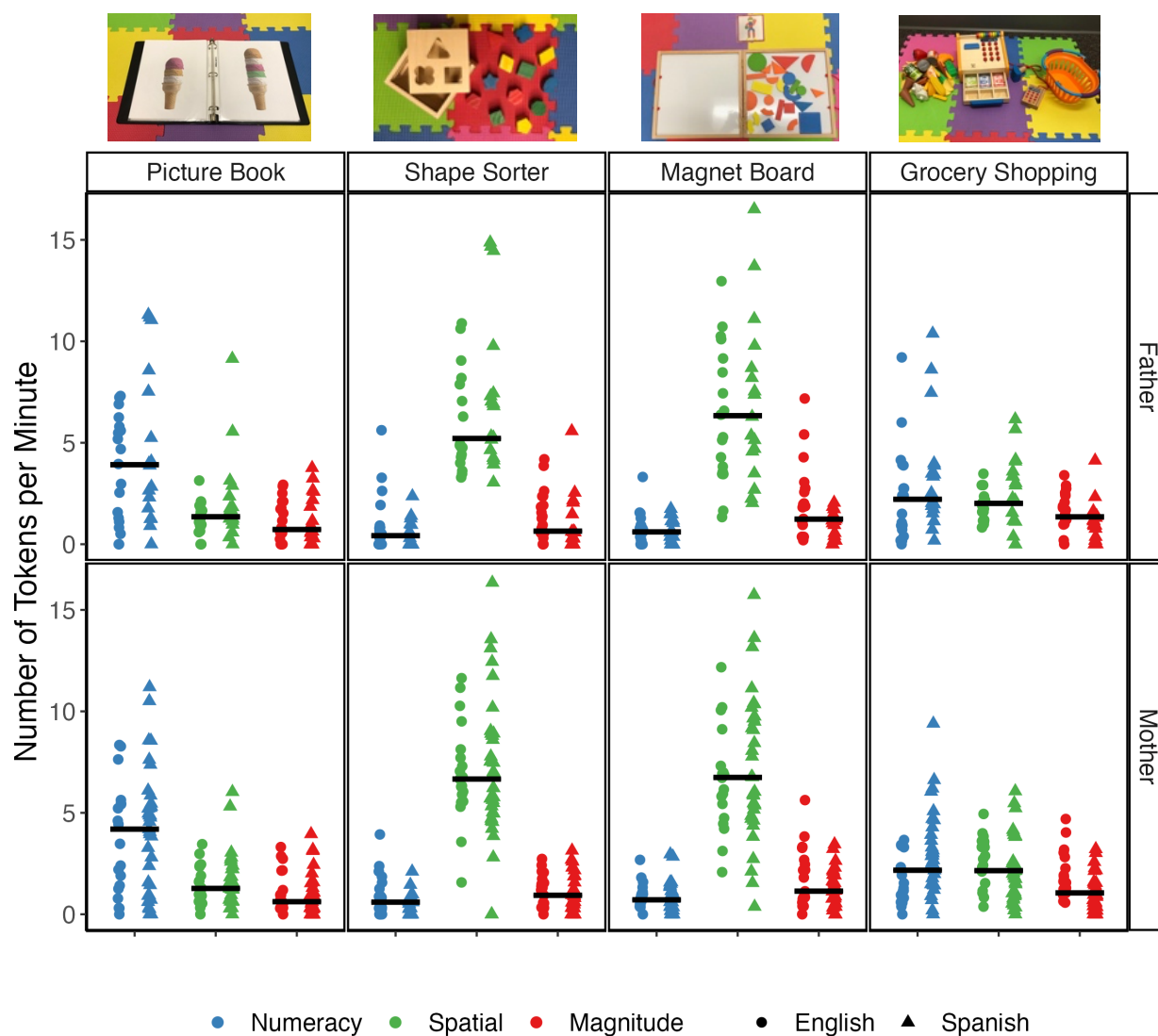
**Table 2. Mean of the natural log-transformed math words per minute by language dominance, play materials, and type of math talk.**

| Type of Math Talk | <u>English-Dominant</u> |                     |                     |                   |
|-------------------|-------------------------|---------------------|---------------------|-------------------|
|                   | Picture Book            | Shape Sorter        | Magnet Board        | Grocery Shopping  |
| Numeracy          | 1.37 <sub>a</sub>       | 0.57 <sub>b</sub>   | 0.53 <sub>b</sub>   | 0.95 <sub>c</sub> |
| Spatial           | 0.75 <sub>a</sub>       | 1.96 <sub>b</sub>   | 1.95 <sub>b</sub>   | 1.12 <sub>c</sub> |
| Magnitude         | 0.67 <sub>a</sub>       | 0.78 <sub>a,b</sub> | 0.97 <sub>b,c</sub> | 1.01 <sub>c</sub> |

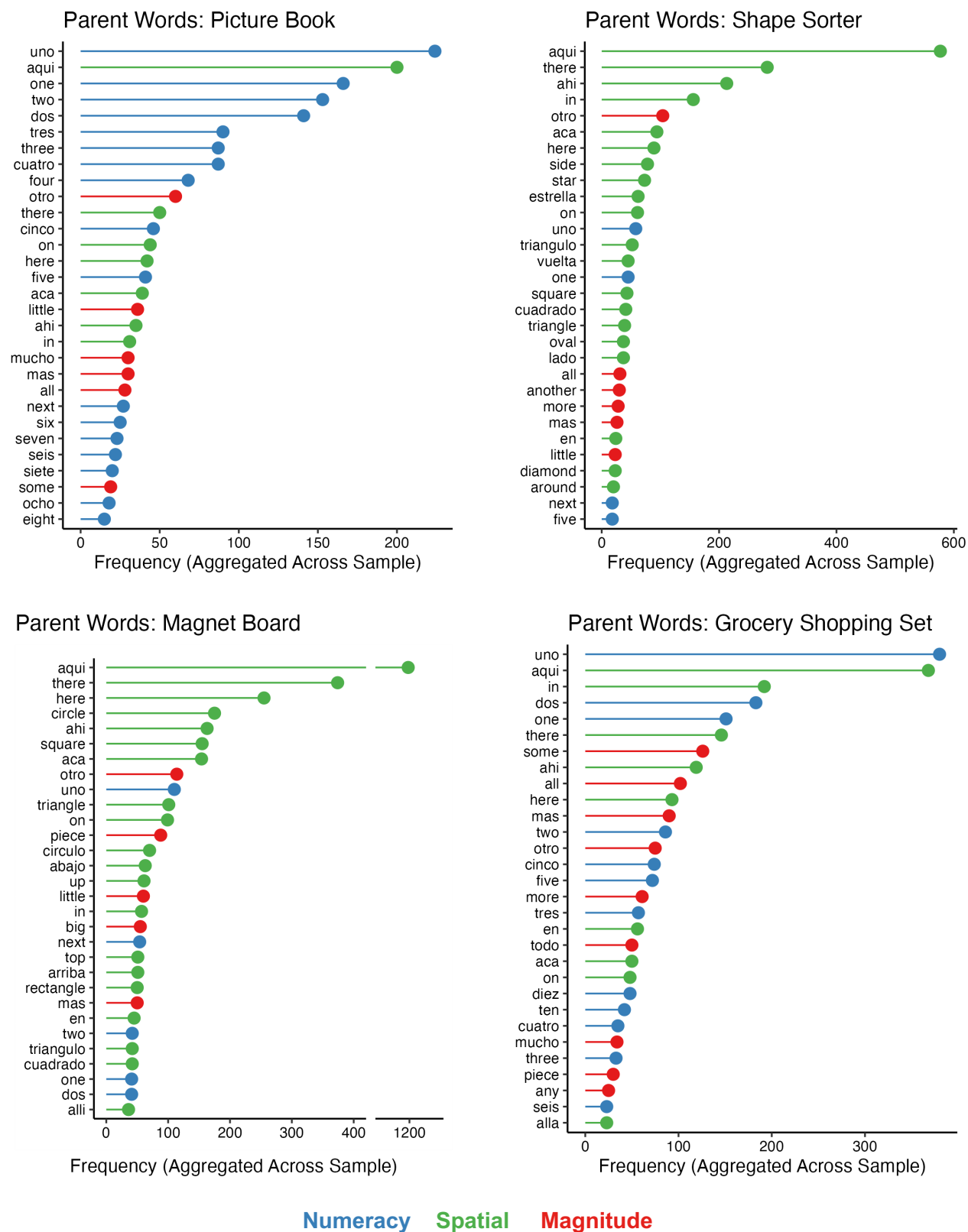
  

|           | <u>Spanish-Dominant</u> |                   |                   |                   |
|-----------|-------------------------|-------------------|-------------------|-------------------|
|           | Picture Book            | Shape Sorter      | Magnet Board      | Grocery Shopping  |
| Numeracy  | 1.42 <sub>a</sub>       | 0.35 <sub>b</sub> | 0.46 <sub>b</sub> | 1.29 <sub>a</sub> |
| Spatial   | 0.88 <sub>a</sub>       | 1.97 <sub>b</sub> | 1.98 <sub>b</sub> | 1.04 <sub>c</sub> |
| Magnitude | 0.57 <sub>a</sub>       | 0.57 <sub>a</sub> | 0.66 <sub>a</sub> | 0.61 <sub>a</sub> |

*Note.* Comparisons are based on type of math talk across the four tasks separately analyzed for English-speaking and Spanish-speaking parents. For each type of math talk, values with different subscripts within a row differ significantly from each other,  $p$ 's < .05.



**Figure 1. Number of math words per minute parents spoke with each type of play material.** Each point represents one parent's word tokens per minute for either numeracy talk (blue), spatial talk (green), or magnitudes (red). Data are depicted for each of the four types of play materials (across the x-axis).



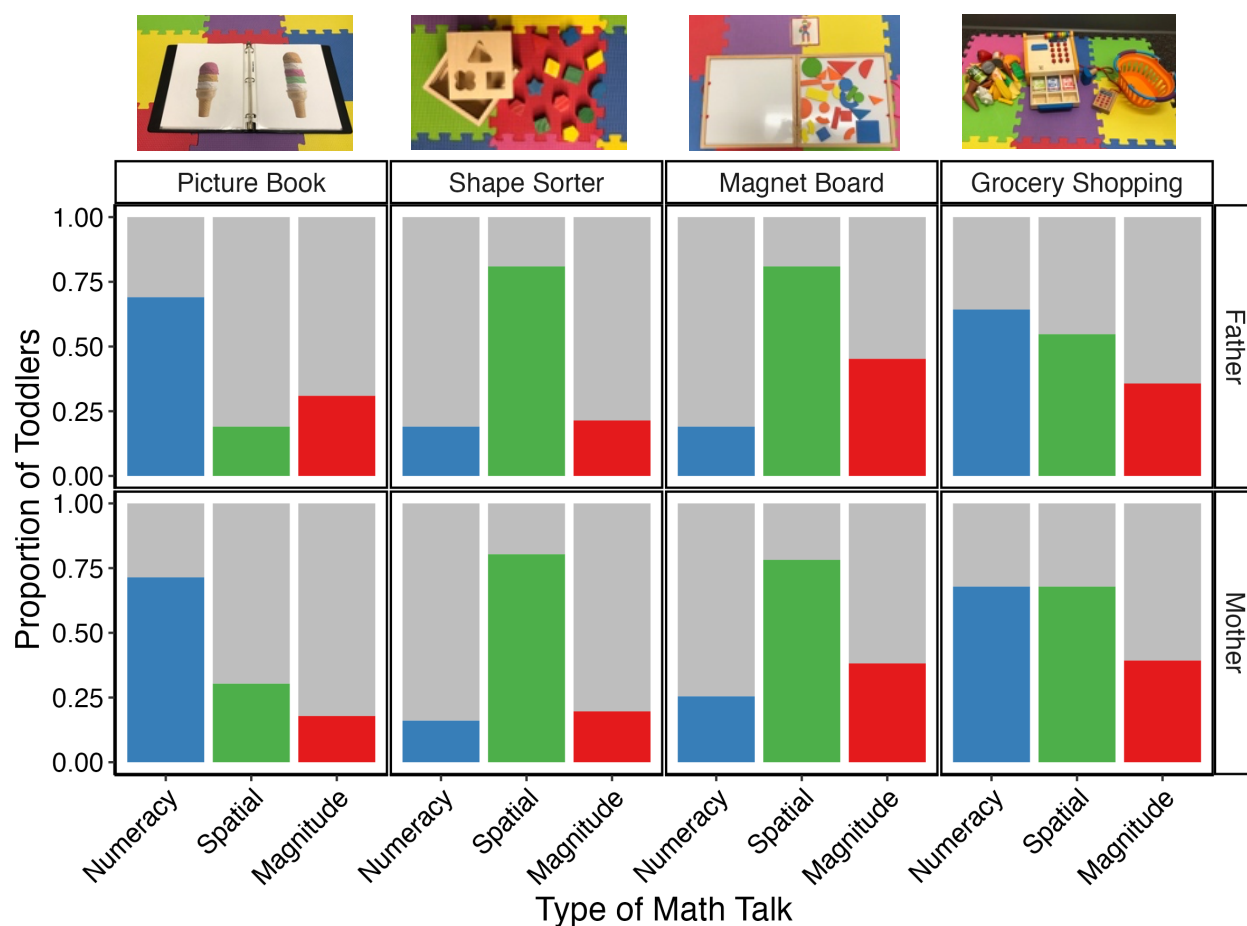
**Figure 2. Most frequent math word types used across parents during each type of play material in English and Spanish.** Frequency was determined based on the number of times

the word was used across all interactions. Words in blue are numeracy, words in green are spatial, and words in red are magnitudes.

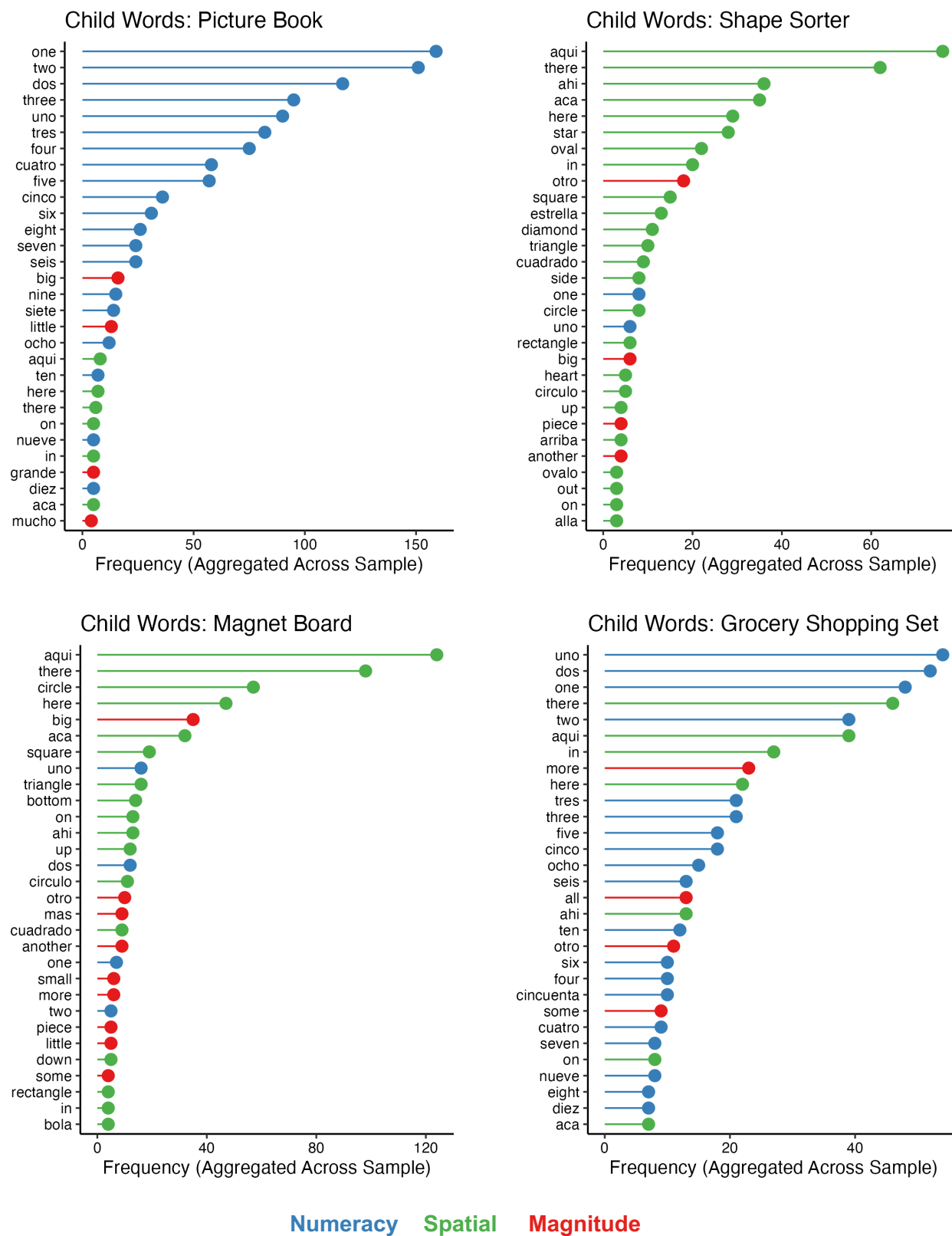
**Table 3. Proportion of interactions in which toddlers produced math talk by type of play material and category of math talk.**

|           | Picture Book       | Shape Sorter         | Magnet Board       | Grocery Shopping Set |
|-----------|--------------------|----------------------|--------------------|----------------------|
| Numeracy  | 0.704 <sub>a</sub> | 0.173 <sub>b</sub>   | 0.227 <sub>b</sub> | 0.663 <sub>a</sub>   |
| Spatial   | 0.255 <sub>a</sub> | 0.806 <sub>b</sub>   | 0.794 <sub>b</sub> | 0.622 <sub>c</sub>   |
| Magnitude | 0.235 <sub>a</sub> | 0.204 <sub>a,b</sub> | 0.412 <sub>c</sub> | 0.377 <sub>b,c</sub> |

*Note.* Comparisons are based on type of math talk across the four tasks separately. For each type of math talk, values with different subscripts across a row differ significantly from each other,  $p$ 's < .05.

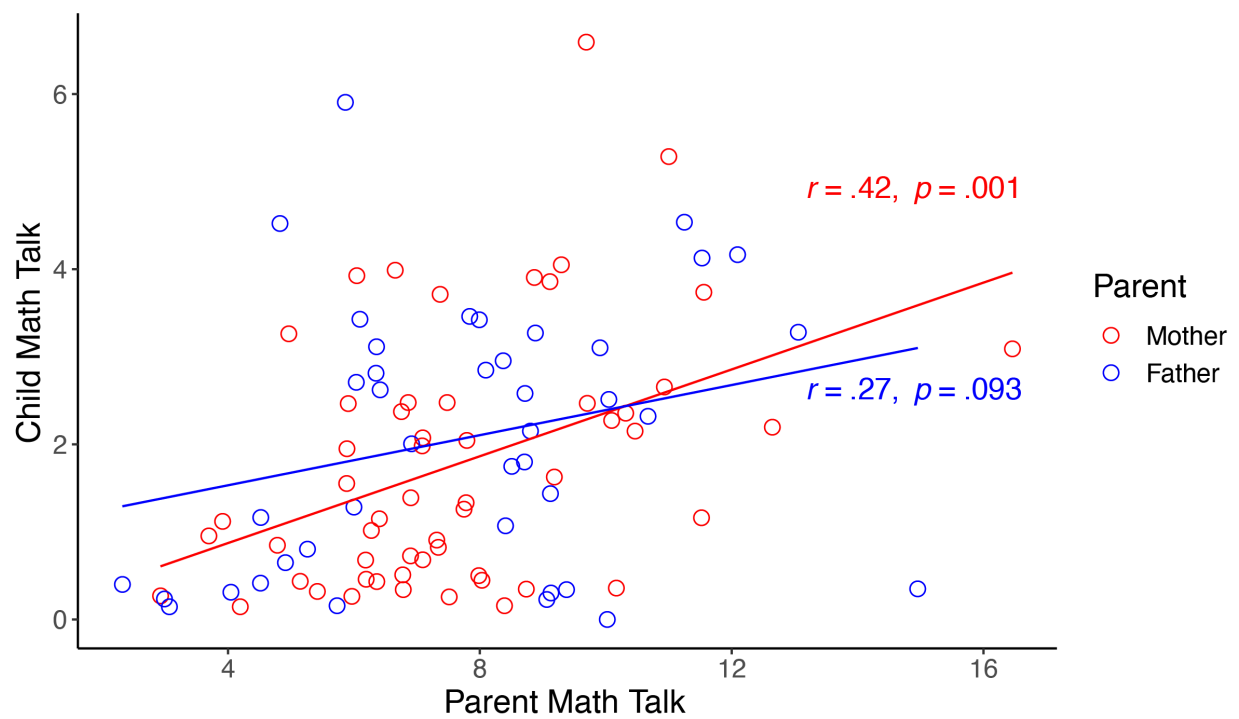


**Figure 3. Proportion of toddlers who used a given category of math talk with each parent and type of play material.** Bars represent the proportion of toddlers who used each type of math talk with their mother or father for numeracy talk (blue), spatial talk (green), or magnitudes (red). Data are depicted for each of the four play materials.

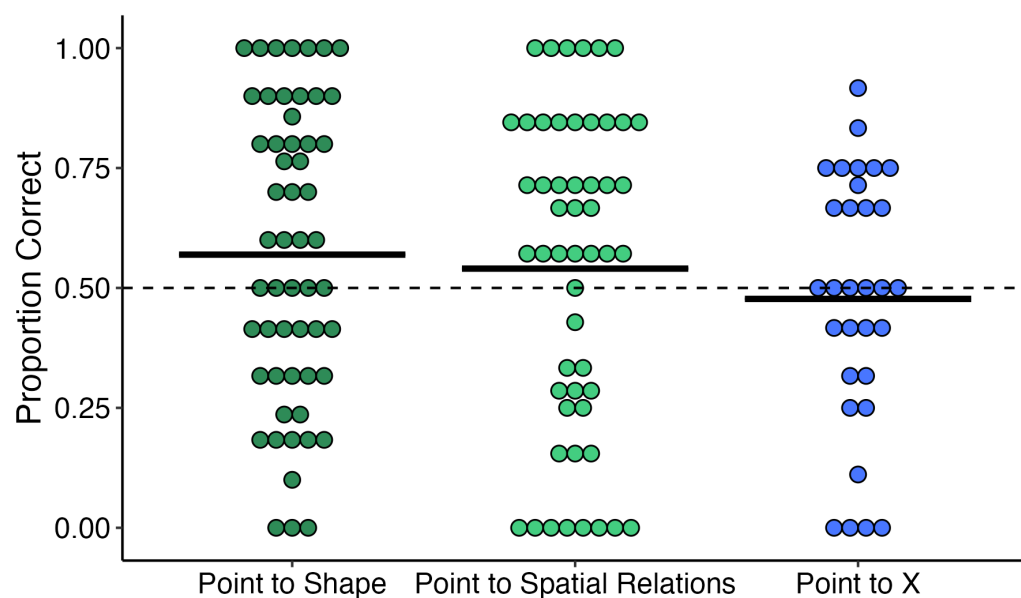


**Figure 4. Most frequent math word types used across toddlers during each type of play material in English and Spanish.** Frequency was determined based on the number of times

the word was used across all interactions. Words in blue are numeracy, words in green are spatial, and words in red are magnitudes.



**Figure 5. Associations between parent and toddler total math talk across play materials.** For both mothers and fathers, when parents used more math talk overall, toddlers used more math talk overall.

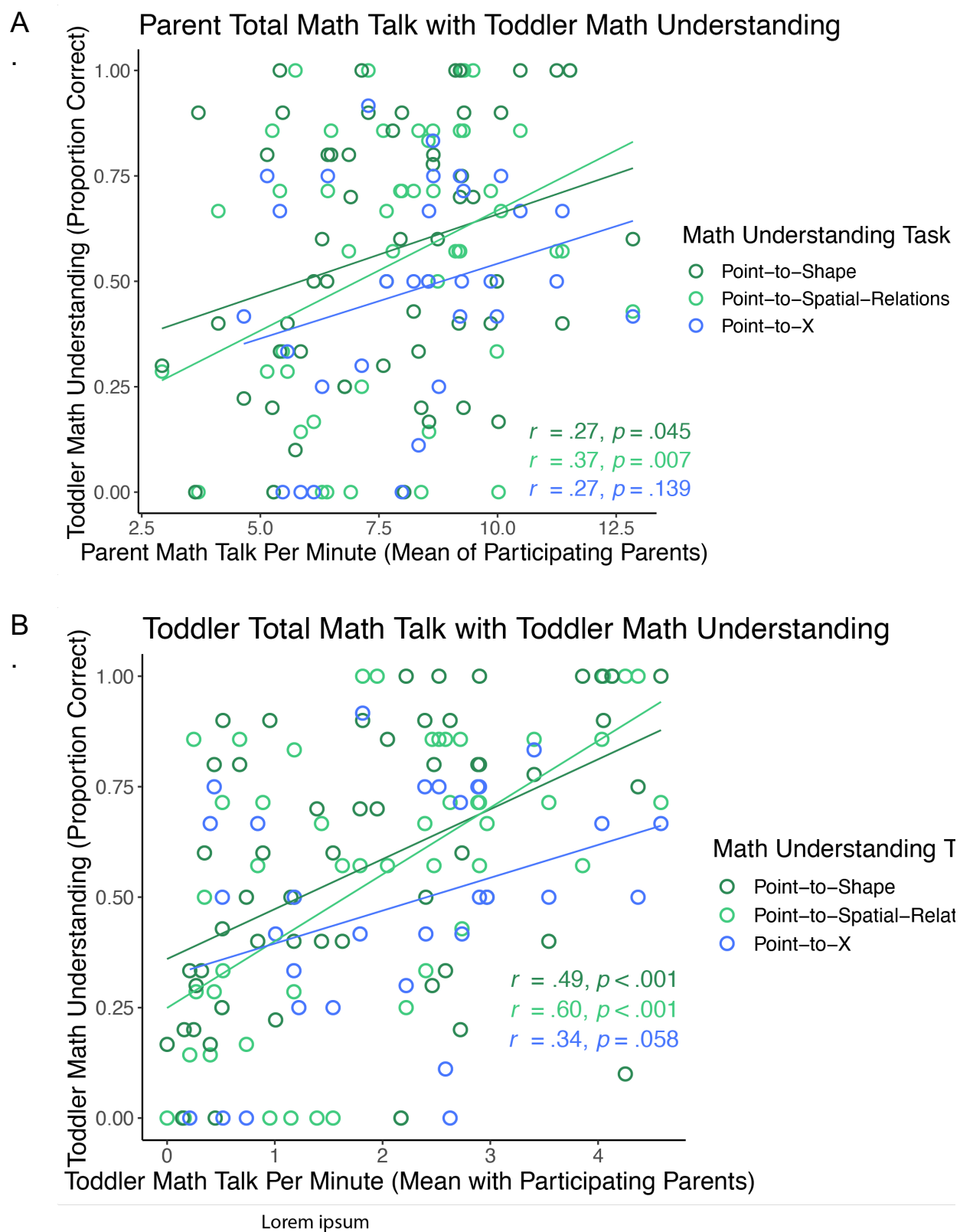


**Figure 6. Toddlers' performance on the three math language comprehension tasks.** Each dot represents one toddler. Black lines for each task represent the average performance across all toddlers. The dashed line represents chance performance. For all tasks, average performance did not significantly differ from chance ( $p$ 's > .05).

**Table 4. Correlations between category of parent math talk and toddler performance on math language comprehension tasks.**

|           | Point-to-Shape |        | Point-to-Spatial Relation |        | Point-to-X |        |
|-----------|----------------|--------|---------------------------|--------|------------|--------|
| Spatial   | .16            | (.33*) | .23                       | (.24)  | .04        | (.00)  |
| Numeracy  | .07            | (.20)  | .31*                      | (.44*) | .21        | (.16)  |
| Magnitude | .43*           | (.47*) | .34*                      | (.15)  | .45*       | (.49*) |

*Note.* Values in parentheses are the correlations between parent math talk and toddler performance controlling for parent age, parent education, parent dominant language, toddler age, toddler gender, total parent utterances. \*  $p < .05$



**Figure 7. Associations between A. parents' use of math talk and toddlers' performance on three math understanding tasks, and B. toddlers' use of math talk and toddlers'**

**performance on three math understanding tasks.** Both parents' and toddlers' use of math talk was associated with toddlers' performance on tasks of math understanding.