Fathers' and Mothers' Praise and Spatial Language During Play With First Graders: Patterns of Interaction and Relations to Math Achievement

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Abstract

Parents provide motivational and cognitive support within the same interaction, yet researchers have investigated these separately. We examined two key aspects of parental support: praise (motivational support) and spatial language (cognitive support) from fathers and mothers during three tasks with their 1st-grade children (6-7-year-olds; *N*=107; 56 girls; 72.0% White, 23.4% Black). Parents' praise and spatial language varied by task but not child sex: both parents produced more praise in the Etch-a-Sketch and block tasks than the card game, and produced more spatial language in the Etch-a-Sketch task than other tasks. We further examined whether praise and spatial language in the two spatial tasks (Etch-a-Sketch and block construction) were related to children's later math and spatial skills. We found neither additive nor multiplicative effects of parents' praise or spatial language. We also did not see additive or multiplicative effects of fathers' and mothers' support. However, fathers' greater spatial language at 1st grade was negatively associated with boys' (but not girls') math achievement in 3rd grade, with greater father spatial tokens related to their sons' lower math achievement. This suggests that boys may perceive fathers' support more negatively than girls do, or that fathers may offer additional support for boys with lower abilities. Taken together, this study emphasizes the importance of considering contexts in examining parental support. The correlational nature of the study warrants future research to establish causal relations and to enhance our understanding of multi-faceted parent-child interactions.

Keywords: father-child interaction; mother-child interaction; parental praise; parental spatial language; academic math achievement; spatial skills

Introduction

Social interactions with parents exert a major impact on children's future cognitive development (Vygotsky, 1980), and parents' beliefs and behaviors shape their children's motivational beliefs and subsequent behaviors (Frome & Eccles, 1998). Parental support during parent-child interactions is multifaceted and includes a variety of parental behaviors that can be broadly categorized as motivational support (parent language and behaviors that foster children's interest, enjoyment, self-concepts, and persistence) and cognitive support (parent language and behaviors that foster children's acquisition of concepts and skills) (e.g., Bradley et al., 2017; Yildiz et al., 2018). The goals of the current study were to examine key aspects of motivational and cognitive support simultaneously in order to improve our understanding of their patterns and relations with children's math and spatial outcomes. In the area of motivational support, we focused on parents' praise, which has been shown to relate to students' later motivation and achievement across academic domains (e.g., Gunderson et al., 2013, 2018). In the area of cognitive support, we focused on parents' spatial language, which has been shown to relate to students' spatial skills (e.g., Pruden et al., 2011), which in turn relate to later math achievement (Newcombe et al., 2019). We examined these two aspects of parental support simultaneously in the same interactions, and asked whether parents' spatial language and praise differ by task type and child sex, and whether parents' spatial language and praise have additive, or potentially multiplicative, effects on children's development.

Examining the role of parental support in promoting children's math and spatial skills is important for increasing children's motivation, skills, and opportunities to succeed in science, technology, engineering, and math (STEM) fields (Casey et al., 2014; Lombardi et al., 2017; Pruden et al., 2011; Thomson et al., 2020). Prior work has established that parental praise and spatial language can each separately impact children's math and spatial motivation and learning. Research has shown that some types of praise are more motivating than others (Mueller & Dweck, 1998). Parental praise for children's ideas, hard work and good strategies (process praise, e.g., "good job drawing the line") has been associated with children's beliefs that intelligence is malleable and their preference for challenge, known as an incremental motivational framework (Gunderson et al., 2013). Children who hold an incremental motivational framework tend to adopt mastery goals and attribute failure to insufficient effort, which leads them to invest more effort in the face of difficulty (Dweck & Leggett, 1988; Hong et al., 1999). These behaviors have been found to predict academic achievement in 1st- and 2nd-grade children (Park et al., 2016) and in older students (Blackwell et al., 2007; Gunderson et al., 2018). Praise without explicit attributions (other praise; e.g., "Awesome!") to children also yielded high persistence and self-evaluations (Morris & Zentall, 2014), whereas praise that emphasized stable traits and fixed quality (person praise, e.g., "you are a really smart kid") tended to lead to a fixed motivational framework. Children who hold a fixed motivational framework tend to have lower motivation after failure and avoid challenges that might reveal that they have low ability, which may impair their performance (Blackwell et al., 2007; Kamins & Dweck, 1999).

Parents' spatial language has also been shown to directly and indirectly facilitate children's spatial skills (Pruden et al., 2011), as it can guide children to attend to relevant spatial features, highlighting those that would otherwise be unnoticed (Ferrara et al., 2011). For example, Pruden et al. (2011) found that parents' use of spatial language during daily routines was related to 14- to 46-month-old children's spatial language, which in turn predicted children's spatial skills.

Studies to date have examined parental praise and spatial language separately to understand their role in promoting children's math and spatial skills. However, parents engage in both of these supportive behaviors within the same interaction. Focusing on only one aspect of parental support at a time is not sufficient to paint a complete picture of parental involvement. Therefore, the primary motive for the current study was to integrate both parental praise and spatial language within a single investigation to explore their patterns and joint associations with children's development. In the following sections, we lay out specific questions that have not been answered by prior literature, with the aim of filling these gaps and enhancing our understanding of parent-child interactions.

Combining Parents' Praise and Spatial Language

First, we asked whether parents' praise and spatial language have additive and synergistic relations with children's later math and spatial skills. Specifically, we were interested in the possibility that parents' motivative praise (e.g., process praise and other praise) creates the conditions under which parents' spatial language can be most effective. High quality parental support involves creating an environment that makes children feel emotionally supported (Grolnick & Slowiaczek, 1994). When the psychological needs for autonomy, competence, and relatedness are not satisfied, parental involvement may be treated as being intrusive and lead to a negative outcome (Deci & Ryan, 1985). In the context of parent-child interactions, it is possible that parents' spatial language is not perceived as supportive by children when parents fail to provide enough praise. Additionally, according to Erikson's theory of psychosocial development, school-aged children are at the critical stage where their sense of competence and inferiority develop (Erikson, 1970). During this stage, parents' feedback may be particularly important in shaping children's self-concept and this relation can be bidirectional. For example, parents' praise to their school-aged children is related to parents' estimation of children's level of self-esteem, such that parents give more inflated praise to low-self-esteem children (Brummelman, Thomaes, Orobio de Castro, et al., 2014; Brummelman, Thomaes, Overbeek, et al., 2014). Consequentially, this can backfire and lead children to avoid challenges because they fear that they will fail to live up to the high standard set by inflated praise (Brummelman et al., 2016). Therefore, it is also possible that parents' praise is not perceived as positive by children when parents provide excessive amounts of cognitive support. However, no studies, to our knowledge, have quantitatively examined both praise and spatial language from parents simultaneously. Some prior work has simultaneously examined positive parenting (e.g., parental warmth and sensitivity) and parental math support (e.g., Zhang et al., 2020). However, even though praise may be related to positive parenting, for reasons stated above, it may act differently on children's development than positive parenting. Therefore, the current study investigated the pattern of parental praise and spatial language during the same parent-child interactions. Moreover, we were interested in the potential interactive relations between these different types of parental supportive behaviors in parent-child spatial tasks and children's long-term math and spatial skill development, which have not been examined in prior studies.

Fathers' Support and Mothers' Support

Second, we examined the relations between both father- and mother-child interactions and children's later math and spatial skills. Researchers have primarily focused on mother-child interactions (for a review, see Cabrera et al., 2018). However, there is evidence that early father-child interactions are positively associated with children's cognitive outcomes and academic success (e.g., Cabrera et al., 2007; Cook et al., 2011). Yet, fathers and mothers may differ in the nature of their responses to children's performance and the effects of their responses on children's outcomes. Fathers tend to follow the child's lead and use more action directives and affirmations (e.g., "Yes", "Good"), whereas mothers tend to teach and repeat their children's utterances more often during parent-child interactions (John et al., 2013). Given these differences, investigating impacts from both parents can more precisely reflect children's experiences than measuring one parent in isolation, as fathers and mothers might provide different amounts and types of support (Clarke-Stewart, 1978). Therefore, it is important to consider how father-child and mother-child interactions are jointly linked to children's development.

Several lines of previous work on parental supportiveness have demonstrated additive (i.e., no moderation) and multiplicative (i.e., moderation) effects of fathers' and mothers' support on children's development (Cook et al., 2011; Martin et al., 2007, 2010; Tamis-LeMonda et al., 2004). For example, 3-year-old children with one supportive parent benefitted on math and language scores regardless of whether the other parent was supportive or not, suggesting an additive effect (Martin et al., 2007). Within the same dataset used in the present study (the NICHD Study of Early Child Care and Youth Development [SECCYD]), researchers found that fathers' supportiveness with their 54-month-old child was associated with children's concurrent and later school readiness only when mothers provided average or low support, suggesting a multiplicative (compensatory) effect (Martin et al., 2010). However, previous work has primarily studied parental support before children enter formal schooling. The pattern of parental support might change, and children might react differently to parental support after children begin school, as children's needs of support to develop skills may vary. For example, parents might interact with children in a more pedagogical manner to support what they learn in schools, and children might require more autonomy support as they age (Pianta & Rimm-Kaufman, 2006).

Therefore, we extended the prior research by examining the potential additive and multiplicative effects of fathers' and mothers' praise and spatial language during interactions with their children at the start of formal schooling (1st grade) on children's later math and spatial skills.

Parents' Support in Different Tasks

Third, we asked whether different types of tasks elicit different amounts of parental praise and spatial language. Parents may provide different amounts of support in tasks that use different play materials (Chan et al., 2020; Lee & Wood, 2020; Verdine et al., 2019), have varying contexts (e.g., home versus lab; Bjorklund et al., 2004; Thippana et al., 2020), and with various play structures (e.g., formal versus playful; Eason & Ramani, 2020; Ferrara et al., 2011; Ramani et al., 2015). Many studies investigating parental praise and spatial language during parent-child interactions have followed parents and children at home, where families were asked to go about their everyday activities and the tasks therefore varied across families (Gunderson et al., 2013, 2018; Pruden et al., 2011; Pruden & Levine, 2017). However, little is known about whether and how praise and spatial language may vary as a function of task type in addition to individual differences across parents.

In particular, studies have suggested that there is a link between parent-child block play and puzzle play and children's spatial and numeracy development (e.g., Levine et al., 2012; Verdine et al., 2014; Wolfgang et al., 2001), yet very little attention has been paid to other types of parent-child tasks that also involve spatial features, such as collaboratively drawing different shapes. Playing with drawing materials relates to children's spatial skills, as drawing demands analyzing, visualizing spatial information and visual-motor coordination (Caldera et al., 1999; Tzuriel & Egozi, 2010; Wai et al., 2009). Further, children play with drawing materials very often at home (Jirout & Newcombe, 2015). It is possible that tasks involve drawing materials and blocks may elicit different types and amounts of parental support, as they may require distinct abilities such as visual-motor coordination in drawing versus perspective taking in block building. By asking parents to complete pre-specified tasks with their child, we can examine whether what, in prior studies, appeared to be individual differences in parents' propensity to use praise or spatial language may in fact be a result of parents' and children's propensity to engage in tasks that elicit those types of language.

In addition to task materials, the play structure of parent-child interaction, such as cooperative play, competitive play, or independent play with some parental support, may also elicit different amounts of parental praise and spatial language. For instance, parents might provide more praise and spatial language in a cooperative task because parent and child share the same goal, in comparison to a competitive task in which the parents' goal is the opposite of the child's. In the current study, the tasks parents and children engaged in varied in both play materials and play structure (a cooperative Etch-a-Sketch drawing game, a semi-independent block construction task, and a competitive card game). Although these tasks were not designed to disentangle the impact of play materials versus play structure on parents' support, they can nevertheless provide a starting point for understanding these effects.

Parents' Support with Sons and Daughters

Fourth, we examined whether parental praise and spatial language are also related to children's sex, once the type of task has been controlled across children. Some prior studies have observed sex differences when the tasks were chosen by children and parents. For example, in terms of parental praise, Gunderson et al. (2013) found that 1- to 3-year-old boys received more process praise than girls from their parents when interacting at home as they usually would, though there were no sex differences in the indirect path from process praise to children's 4th-

grade math achievement (Gunderson et al., 2018). Regarding parental spatial language, Pruden and Levine (2017) also observed that 14- to 46-month boys heard more spatial language than girls, again during everyday home tasks. It is important to note that the above-mentioned studies happened in naturalist contexts where parents and children could play with different materials. As a result, it is possible that parents were more likely to choose tasks that stimulated praise and spatial language with boys than with girls. In a study where tasks were controlled across children, Ralph et al. (2021) found that mothers used more spatial language with their pre-kindergarten boys than with girls while playing with magnetic tile toys; however, this relation was reversed in kindergarten and first-graders, at which age girls received more spatial language than boys. It should be noted that in Ralph et al. (2021), kindergarten and 1st grade boys still outperformed girls on a subsequent mental rotation task despite having less exposure to spatial talk than girls. In a similar age group, however, Thomson et al. (2020) did not find child sex differences in parental spatial language production with their 1st-grade boys and girls in a block building task.

These mixed results raise two issues which merit more research. First, child sex might not necessarily be the driving factor in parental spatial language production, but other factors, such as task type and age, might be more important predictors. Second, fathers' and mothers' support might have different associations with boys' and girls' skill development, which warrants the need to include both parents in a single study. Therefore, we aimed to examine how parents provide praise and spatial language to boys and girls under controlled task conditions, and whether parental support has different relations to boys' and girls' later math and spatial skill development.

The Current Study

In order to answer the questions above, the current study examined the pattern of both parental praise and parental spatial language at school entry during father-child and mother-child interactions and their impacts on children's spatial skills and math achievement at a later point. We started by investigating whether parents' praise and spatial language differed by tasks and child sex. Parents and their 1st-grade child engaged in three tasks: (1) an Etch-a-Sketch joint task; (2) a block task; and (3) a card game (see details in the Procedure section). We examined whether parental praise and spatial language differed in these three tasks, each involving different spatial features and requiring varied types of parental engagement, and whether parent praise and spatial language differed for boys and girls.

Secondly, we examined whether parental praise and spatial language were associated with children's long-term outcomes including math achievement at 3rd-grade and spatial skills at 4th-grade, controlling for 1st-grade math achievement (i.e., additive effects of parents' praise and spatial language). For these analyses, we examined parental support during the first two spatial tasks (the Etch-a-Sketch and block tasks), because we expected these tasks to be a good indicator of parents' spatially-relevant interactions with their child. Thirdly, we investigated whether parental praise and spatial language showed a multiplicative effect in predicting children's 3rd-grade math achievement and 4th-grade spatial skills (e.g., a more positive effect of spatial language in the context of high praise). Moreover, we explored whether support from one parent was moderated by that from another parent regarding its relation to children's outcomes (a multiplicative effect across the two parents). Lastly, we studied whether parental support had different relations to boys' and girls' long-term math achievement and spatial skills.

To test these questions, we used videotapes collected as part of the NICHD Study of Early Child Care and Youth Development (SECCYD). This longitudinal dataset enabled us to examine the associations of these interactions with children's later math achievement and spatial skills while controlling for children's current math achievement. It is important to note that there have been other studies examining the impact of parental support on children's math and spatial skills in the SECCYD dataset (e.g., Casey et al., 2016; Lombardi et al., 2017; Thomson et al., 2020). For example, Thomson et al. (2020) examined parental spatial support in 1st-grade children (same time point as the current study) using data collected at a different site included in the SECCYD dataset. They measured the quality of fathers' spatial concept support during block building and found that fathers' high spatial concept support was positively related to their 1st-grade girls' (but not boys') superior math achievement. Building on prior findings and being motivated by our research questions, the current study included both praise and spatial language from both mothers and fathers and examined different tasks that parents and children played. Moreover, we investigated associations with children's achievement and skills at much later points (3rd-grade and 4th-grade) to detect the long-term impacts of parental support. Therefore, the current study aimed to extend the findings of previous studies, to explore the frequency of parental support in different tasks and across child sex, and to explore the additive and multiplicative relations of parents' support to children's later math and spatial outcomes.

Method

Participants

The current study used data from the Philadelphia site of the NICHD Study of Early Child Care and Youth Development (SECCYD; NICHD Early Child Care Research Network, 2001). In 1991, researchers at that site recruited 136 mothers and their recently-born children using a conditionally random sampling plan (for details, see NICHD Early Child Care Research Network, 2001). The current investigation focused on coding videotaped data already recorded in father-child and mother-child interactions when children were in 1st grade (*N* = 107, 56 girls) and correlating newly coded data with standardized scores collected from these same children when they were in 3rd and 4th grades. According to mothers' reports (*N* = 107), 72.0% of the children were White, 23.4% were Black or African-American, 0.9% Asian or Pacific Islander, and 3.7% other race/ethnicity.

For the analyses reported in this paper, we included only children who interacted with their biological father or step-father (referred to hereafter as "fathers") when examining questions involving father-child interactions. We excluded one mother-child pair because the videotaped interaction was too blurry to transcribe. In total, we analyzed videotapes from 77 children (42 girls; age: *M* = 6.67 years, *SD* = 0.35) interacting with their father and 104 children (55 girls; age: *M* = 7.13 years, *SD* = 0.35) interacting with their mother. There were 74 children observed interacting with both parents.

Procedure

Father-Child Interaction

The 15- to 20-minute father-child interaction took place in the fall of the child's 1st grade year during a semi-structured teaching and play situation in the child's home. Father and child completed three tasks, selected to be fun but challenging: (1) an Etch-a-Sketch task where one controlled the vertical knob and the other controlled the horizontal knob to draw a sailboat; (2) a block building task where the child was asked to build 3-D designs using color cubes by copying pictures of the design, with the father's assistance as needed; (3) a "Slap Jack" card game where the father and child took turns placing one card at a time in a pile, until a "Jack" was turned up, at which point the first one to slap the pile won all the cards in the pile.

Mother-Child Interaction

Mothers and children were videotaped in a 15- to 20-minute semi-structured teaching and play situation at the university research lab in the spring of the child's 1st grade year. Similar to the father-child interaction, mother and child completed three tasks: (1) an Etch-A-Sketch task where one person controlled the vertical knob and the other controlled the horizontal knob to draw a house and tree; (2) a pattern block task where the child was asked to fill in a 12 sided polygon using colored shapes in two different ways, with the mother assisting as needed; (3) a "One-up; One-down" card game where the mother and child took turns placing one card at a time in a pile, until the card turned up was one less than or one greater than the previous card, at which point the first one to slap the pile won all the cards in the pile.

Video Transcription

For this study, trained research assistants used Datavyu (Datavyu Team, 2014) to transcribe parental speech. All speech was separated into utterances. An utterance could be a word, a short phrase, or a complex sentence with embedded clauses, preceded and followed by a pause, change of intonational pattern, or conversational turn. To ensure reliability, a second coder transcribed 20% of transcripts. Reliability was assessed at the word level and the utterance level. Disagreements were resolved when agreement was under 85% at either word level or the utterance level. The median Cohen's kappa was 0.86 at the word level and 0.91 at the utterance level.

Measures

Parental Praise

Research assistants coded parental praise based on the transcripts within Datavyu (Datavyu Team, 2014). Consistent with Gunderson et al. (2013), we defined parental praise as parents' positive speech about their child that occurred during or after the action being referenced. The positive valence could be either explicit (e.g., containing words such as *good* and *great*) or implicit (affirmations without explicit positive words, for example, "You did it!"). Trained research assistants coded parental praise instances from the Datavyu transcript. To resolve ambiguities (e.g., parent used "There you go" as an affirmation instead of handing child an item), the coders also examined the videotaped sequences. We used instances as the unit for parental praise, as sometimes utterances contained multiple praise instances (e.g., an utterance like "good -- that's a good idea using those" would be coded as two praise instances, separated by the dashes). As mentioned earlier, the previous literature generally identified three types of praise: process praise, other praise, and person praise (Gunderson et al., 2013). However, researchers have consistently found that person praise led children to believe that intelligence is fixed and further showed decrements in performance, compared to process praise and other praise (e.g., Kamins & Dweck, 1999; Morris & Zentall, 2014). Given that our goal was to examine the potential positive impacts of parents' praise on children's later achievement, we excluded parental person praise, which would be expected to either have no effect or work against the predicted positive effects of process and other praise. Therefore, we focused on only process praise and other praise in our current study[1]. Process praise was defined as praise emphasizing a child's effort (e.g., "You did a great job!"), actions (e.g., "good turning"), or strategies and ideas (e.g., "I like how you put that together"). Other praise included general praise statement that were not verbally explicit in their referent (e.g., "Good!" or "Nice!"),

[1] As a check, we also tested the possibility that person praise may interact with process praise and other praise in explaining children's math and spatial outcomes. Person praise was very rare in our sample (mean of .39 instances from fathers and .61 instances from mothers, compared to a mean of 18.45 and 14.60 instances of process plus other praise from fathers and mothers, respectively). Nevertheless, as a check, we reran the analyses shown in Table 2 while adding paternal and maternal person praise as simultaneous predictors in each model. Parental person praise was not significant in either model, and the results reported as significant remained significant. Our further inclusion of the interaction between person praise and the combination of process and other praise did not yield any significant interactions (interaction terms *p*s $\geq$ .221).

affirmations of children's actions (e.g., "You did it!"), or statements that emphasized the product or outcome of a child's action (e.g., "We made a neat looking boat"). We used the raw summation of process praise and other praise instances as the index of parental praise and later adjusted these counts for differences in the duration of the interaction in our analyses.

To establish inter-rater reliability, 20% of each coder's videos were coded independently by a second coder. Disagreements were discussed and resolved. Reliability among the coders was high, with median Cohen's kappa value of .90 (Cohen, 1960).

Parental Spatial Language

Research assistants coded parental spatial language based on transcripts within Datavyu (Datavyu Team, 2014). We coded eight categories of spatial words based on Cannon et al. (2007): spatial dimensions (sizes of objects and spaces; e.g., large, wide, deep), shapes (forms of objects and spaces; e.g., circle, sphere), locations and directions (relative positions of objects and points in space; e.g., in, under, below), orientations and transformations (relative orientations or transformations of objects in space; e.g., upside down), continuous amounts (amount of continuous quantities; e.g., part, half), deictics (place deictics; e.g., here), spatial features and properties (features and properties of objects and spaces; e.g., side, curve), and patterns (words that indicate a person may be talking about a spatial pattern; e.g., sequence). In addition to the specific words in Cannon et al. (2007), two of the authors read all unique words used in these transcripts and identified another 86 spatial terms. We only coded target words that were used in a spatial manner (e.g., "ups and downs" was excluded when used to refer to the card game). For each parent-child dyad, we calculated the frequency of the parent's use of spatial words (e.g., total count of spatial word *tokens* used by parents during the interaction) and the frequency of unique spatial words (e.g., total count of spatial word *types* used by parents during the interaction). For example, the utterance "This triangle is taller than that triangle" contains 3 spatial tokens (*triangle*, *taller*, and *triangle*) but only 2 spatial types (the unique spatial words, *triangle* and *taller*). We calculated the raw counts of spatial tokens and types and later adjusted these counts for differences in the duration of the interaction in our analyses.

For inter-rater reliabilities, 20% of each coder's videos were coded independently by a second coder. Disagreements were discussed and resolved. We calculated Cohen's kappa at the spatial word level and the median kappa value was .83.

Duration of Task Time

We coded duration of time spent on each task in the parent-child interaction from the time the parent took out the task materials (e.g., Etch-a-Sketch board) to the time when the parent put the task materials away (M = 5.31 mins per task, SD = 2.23 mins). We excluded interaction data from any task that took less than two minutes.

Children's Mathematics Achievement

Children's mathematics achievement was assessed in the spring of first grade (age: M = 7.13 years, SD = 0.35) and third grade (age: M = 9.10 years, SD = 0.32), using the Applied Problem subtest of the Revised Woodcock-Johnson Tests of Achievement (McGrew et al., 1991; Woodcock et al., 1989). The Applied Problem test measured children's skill in analyzing and solving practical mathematical problems. In these grade levels, problems typically include application of math knowledge and simple arithmetic calculation. We used W scores, which are a special transformation of the Rasch ability scale, in our analyses.

Children's Spatial Skills

Children's spatial skills were assessed in fourth grade (age: M = 10.00 years, SD = 0.31), using the Block Design subtest of the Wechsler Abbreviated Scale of Intelligence (WASI;

Psychological Corporation, 1999). The Block Design test measures children's ability to copy abstract designs using blocks. We used children's T scores, which were converted from their raw scores, as the index of children's spatial skills in 4th grade.

Child and Family Covariates

We included control variables that had exhibited correlations with children's math achievement and spatial skills, and had been included in a prior study that examined 1st graders' math achievement from a different site of the SECCYD dataset (Thomson et al., 2020). These included child ethnicity (two dummy coded variables; one coded African American as 1 and other races as 0, the other one coded European American as 1 and other races as 0), child sex, and maternal years of education when children were 1 month old[2]. In the SECCYD dataset, a ratio of income-to-needs was computed by dividing the total family income at each observation by the poverty threshold for a household of that size. We calculated the average of income-to-needs ratio across seven observations (1, 6, 15, 24, 36, 54 months, and 1st grade) and used it in our analyses. Similarly, we also calculated the average of maternal partner status across the same seven observations, with 1 indicating married or partnered and 0 otherwise (e.g., single, separated, or divorced). We also included a measure of child's mental development using the Revised Bayley Scales of Infant Development at 24 months (Bayley, 1993). The Bayley is widely used to assess children's cognitive and language development in the first two years of life. Additionally, we included ratings of parental stimulation of cognitive development, which had been previously coded in the SECCYD dataset based on the same 1st grade parent-child

[2] As a robustness check, we conducted the reported analyses using the maximum years of education of the mother or mother's partner (both reported by the mother when children were 1 month old). The pattern of results remained the same as in the main text. We chose to use maternal education in our main analyses because the mother's partner at child age 1 month may not, in all cases, have been the same individual who completed the father video observations at child age 1st grade.

interaction videos used in our study. Parental stimulation of cognitive development was assessed across all three parent-child activities and aimed to capture parents' level of general support in enhancing the child's learning experience. Scores ranged from 1 to 7, with 1 indicating that parents made no attempt to stimulate or teach the child anything and 7 indicating that parents constantly stimulated a high level of mastery, understanding, or sophistication and taking advantage of these activities as a learning experience for the child.

Missing Data

Given the longitudinal nature of the study design, some measures were lost to attrition and item non-response. Within our analytic sample ($N = 107$), 28% were missing father-child interaction data (due to having no interaction recorded [18.7%] or an interaction that we excluded because it was with a non-father adult [9.3%]) and 2.8% were missing mother-child interaction data (due to having no interaction recorded [1.9%] or an interaction that we excluded because it was too blurry to transcribe and code [0.9%]). There was a small amount of missing data on the covariates: 1.9% were missing children's 2-year-old mental development score and 1.9% were missing 1st-grade math achievement. Family income-to-needs ratio and maternal partner status had a small amount of missing data across seven observations, ranging from 0% to 7.5%; because we averaged across the available observations, our composite measures for these variables had zero missing data. Among our dependent variables, children's 3rd-grade math achievement was missing for 15.9% of the sample and 4th-grade spatial skills was missing for 17.8%.

We examined all variables used in our analyses as predictors of whether children were missing data for the 3rd-grade math achievement and 4th-grade spatial skills separately, using multiple probit regression (Eisner et al., 2019). No predictors were related to missingness of outcome data (*p*s ≥ .154). To test whether the data were missing completely at random (MCAR), we conducted Little's MCAR test, which was not significant, $\chi^2(164) = 166.5$, $p = .431$. This is consistent with data being MCAR and lends support to our approach of using full information maximum likelihood (FIML) to provide bias-reduced model estimates (Acock, 2012).

Transparency and Openness

We report the scope of the sample, all data exclusions and all relevant measures that were used in the current analyses. The original NICHD SECCYD data are archived at ICPSR (U.S. Department of Health and Human Services, 2018a, 2018b, 2018c). This study was not preregistered. The study was determined to not be research involving human subjects by the Temple University Institutional Review Board (Protocol 24308: Early childhood interactions and later STEM achievement and attitudes). We used R 3.6.3 (R Core Team, 2020), and the packages tidyverse (Wickham et al., 2019), geepack (Højsgaard et al., 2005), lavaan (Rosseel, 2012), and ggplot2 (Wickham, 2009) to manage, model, and graph the data.

Analytic Plan

We first examined whether parents' praise and spatial language differed by task type and child sex. We conducted separate Poisson log linear generalized estimating equation models (GEEs; Liang & Zeger, 1986) on parental praise and spatial language. We controlled for the time that parents spent on each task by calculating praise and spatial language per minute scores. We also modeled father-child and mother-child interactions separately because the tasks each parent completed with their child were not exactly the same, and because our research questions did not involve comparing fathers to mothers in terms of their praise and spatial language. In each model, we included child sex, task, and the interaction between child sex and task. The GEE approach, as an extension of generalized linear models, allowed us to model population-average effects while accounting for the within-subject measurements (e.g., task), and to explicitly model dependent variables with non-normal distributions (in our case, modeling rates of count data per minute, using the Poisson distribution). We followed up on significant effects using pairwise comparisons with Holm's Bonferroni corrections, and report effect sizes using the rate ratio (*RR*), where *RR* = rate1 / rate2.

We secondly investigated whether and how parental motivational and cognitive support in spatial tasks were related to children's 3rd-grade math achievement and 4th-grade spatial skills. We therefore included only the spatial tasks (Etch-a-Sketch and block tasks) in these analyses. We modeled praise and spatial language (spatial tokens or spatial types) from mothers and fathers in the same model, which included only children who had both paternal and maternal interaction data. Here, we included both fathers and mothers, consistent with our research aim to understand their unique and interactive contributions to children's development. We used language per minute variables to rule out the possibility that parents' support measures were primarily determined by the time they spent on that task. These praise instances per minute and spatial language per minute variables were then square-root transformed to achieve better normality. We used full information maximum likelihood estimation to handle the missing data in each model. To examine whether parental praise and spatial language were related to children's math and spatial skills, we conducted linear regressions and separately regressed 3rd-grade math achievement and 4th-grade spatial skills on mothers' and fathers' praise and spatial language, controlling for 1st-grade math achievement, child sex, and child and family covariates. We separated spatial tokens and spatial types in different models to avoid collinearity.

We thirdly examined whether the relations of parental praise and spatial language to children's outcomes were additive or multiplicative. To do so, we conducted linear regressions including the interactions between praise and spatial language from each parent, controlling for prior achievement, child sex, and child and family covariates.

We then examined whether there were multiplicative relations of paternal support and maternal support to children's academic outcomes. In other words, we asked whether the relation between children's academic outcomes and paternal support was conditional on maternal support, and vice versa. We modeled the interactions between paternal and maternal praise, along with paternal and maternal spatial language in linear regressions, controlling for prior 1st-grade math achievement, child sex, and child and family covariates.

Lastly, we explored whether parental support had different relations to boys' and girls' math achievement and spatial skills. We modeled the interactions between each type of parental support and child sex in linear regressions with the same set of control variables.

To estimate power for these regression models, we conducted a sensitivity analysis in G*Power 3.1 (Faul et al., 2009) with the parameters $\alpha = .05$, power = .80, sample size = 107, and number of predictors = 18 (the maximum in any regression). With these parameters, the smallest detectable effect size is $f^2 = .075$, a small-to-medium effect (where small is $f^2 = .02$ and medium $f^2 = .13$; Cohen, 1988). We used Bonferroni corrections to control the overall Type I error for our regression analyses that examined the relations between parental support and children's math achievement and spatial skills. For 16 regression models, the corrected alpha level was .003.

Results

Preliminary Analyses

We examined zero-order correlations for all variables (see Supplemental Table S1 for descriptives and correlations). For these analyses, we aggregated parental praise and parental spatial language across all three tasks. Overall, mother's praise was positively and significantly correlated with mothers' spatial language (both tokens and types, *r*s = .23 and .40, *p*s ≤ .020), but this was not the case for fathers (both tokens and types, *r*s = .09 and .16, *p*s ≥ .172). Mothers' praise was *positively* correlated with children's math achievement and spatial skills (*r*s = .26 to .32, *p*s ≤ .013), whereas fathers' spatial tokens were *negatively* correlated with children's 1st- and 3rd-grade math achievement and 4th-grade spatial skills (*r*s = -.36 to -.30, *p*s ≤ .015)[3]. However, mothers' spatial tokens and types and fathers' praise were not significantly correlated with children's math and spatial outcomes (*p*s ≥ .206).

Did Parental Praise and Spatial Language Differ by Task Type and Child Sex?

Parental Praise

Separately for mothers and fathers, we conducted GEE models regressing parental praise instances per minute (referred to hereafter as "praise") on task type, child sex, and the interaction between task and child sex. For father-child interactions, praise did not differ by child sex, but differed by task (see Table 1, Model 1 and Figure 1). The interaction of Child Sex × Task Type was not significant, suggesting that the amount of maternal praise that boys and girls received was not dependent on the task type. Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that fathers gave significantly more praise in the Etch-a-Sketch task (estimated marginal *M* = 1.71, *SE* = 0.15) than the block task (estimated marginal *M* = 1.17, *SE* = 0.11, adjusted *p* < .001; Etch-a-Sketch vs. blocks rate ratio (*RR*) = 1.46) and the card game (estimated marginal *M* = 0.35, *SE* = 0.05, adjusted *p* < .001; Etch-a-Sketch vs. card game *RR* = 4.97). Fathers also provided more praise in the block task than the card game (adjusted *p* < .001,

[3] We examined the NICHD SECCYD ratings of parent-child interaction quality, which included ratings of parent's respect of child's autonomy. We correlated this autonomy support rating with parental motivational and cognitive support and found that mother's respect for autonomy was positively and significantly correlated with maternal praise (*r*(104) = .40, *p* < .001) and maternal spatial types (*r*(104) = .24, *p* = .016), whereas father's respect for autonomy was only negatively and significantly correlated with paternal spatial tokens (*r*(77) = -.26, *p* = .021). These results suggest that fathers who used more spatial language may have provided an unnecessary amount of support, and this support may have restricted the child's autonomy.

blocks vs. card game *RR* = 3.40).

Praise in mother-child interactions followed the same pattern. Praise did not differ by child sex, but differed by task, and there was no significant Child Sex × Task interaction (Table 1, Model 2, and Figure 1). Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that mothers provided significantly more praise in the Etch-a-Sketch task (estimated marginal *M* = 1.11, *SE* = 0.09) and in the block task (estimated marginal *M* = 1.19, *SE* = 0.08) than in the card game (estimated marginal *M* = 0.44, *SE* = 0.04, adjusted *p*s < .001; Etch-a-Sketch vs. card game *RR* = 2.56; blocks vs. card game *RR* = 2.74).

To summarize, parental motivational support differed by task types but not child sex. Both fathers and mothers provided more motivational support in the two spatial tasks (the Etch-a-Sketch and block tasks) than the card game[4].

Parental Spatial Tokens

Separately for fathers and mothers, we conducted GEE models regressing parental spatial tokens per minute (referred to hereafter as "spatial tokens") on task type, child sex, and the interaction between task and child sex. For father-child interactions, task was significant but neither child sex, nor Child Sex × Task Type were significant (see Table 1, Model 3 and Figure 1). Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that fathers produced significantly more spatial tokens in the Etch-a-Sketch task (estimated marginal *M* = 15.28, *SE* = 0.63) than the block task (estimated marginal *M* = 5.19, *SE* = 0.38, adjusted *p* < .001, Etch-a-Sketch vs. blocks *RR* = 2.94), and the card game (estimated marginal *M* = 4.42, *SE* =

[4] We reran these analyses with process praise only as the DV, in order to compare our results more directly with the sex differences in process praise reported in Gunderson et al. (2013). We controlled the length of time spent on each task. We did not find significant differences in process praise from fathers to boys versus girls (boys' estimated marginal *M* = 0.13, *SE* = 0.02; girls' estimated marginal *M* = 0.08, *SE* = 0.02, adjusted *p* = .068), nor from mothers (boys' estimated marginal *M* = 0.09, *SE* = 0.02; girls' estimated marginal *M* = 0.11, *SE* = 0.02, adjusted *p* = .420). These results suggested that parental praise might be driven by other factors, such as task, than child sex.

0.38, adjusted $p < .001$; Etch-a-Sketch vs. card game *RR* = 3.45). Similarly, for mother-child interactions, task was the only significant variable (Table 1, Model 4). Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that mothers used significantly more spatial tokens in the Etch-a-Sketch task (estimated marginal *M* = 14.82, *SE* = 0.57) than the block task (estimated marginal *M* = 3.92, *SE* = 0.24, adjusted $p < .001$, Etch-a-Sketch vs. blocks *RR* = 3.78), and the card game (estimated marginal *M* = 4.35, *SE* = 0.25, adjusted $p < .001$; Etch-a-Sketch vs. card game *RR* = 3.41).[5]

Parental Spatial Types

For fathers' use of spatial types, task was significant (see Table 1, Model 5 and Figure 1). However, spatial types did not differ by child sex, and the interaction of Child Sex × Task Type was not significant. Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that fathers had significantly more spatial types in the Etch-a-Sketch task (estimated marginal *M* = 4.74, *SE* = 0.19) than the block task (estimated marginal *M* = 2.21, *SE* = 0.11, adjusted $p < .001$, Etch-a-Sketch vs. blocks *RR* = 2.14), and than the card game (estimated marginal *M* = 1.98, *SE* = 0.11, adjusted $p < .001$, Etch-a-Sketch vs. card game *RR* = 2.40). For mothers' use of spatial types, task was the only significant variable (Table 1, Model 6). Pairwise comparisons using Holm's Bonferroni corrections showed that mothers produced significantly more spatial types in the Etch-a-Sketch task (estimated marginal *M* = 4.04, *SE* = 0.13) than the block task (estimated marginal *M* = 2.01, *SE* = 0.10, adjusted $p < .001$; Etch-a-Sketch vs. blocks

[5] We conducted a robustness check using the "what" spatial word categories that were used in Pruden and Levine (2017), i.e., dimensional adjectives, shape terms, and spatial features and properties. We did not find any child sex differences in parental use of spatial language, yet we did find that, similar to our current results, both fathers and mothers used more spatial language in the Etch-a-Sketch game than the block task and the card game (*p*s < .001). Moreover, both parents produced more spatial language in the block task than the card game (*p*s < .001). We further replaced parental spatial language with "what" spatial language in examining the relation of parental support to child's math and spatial outcomes. After Bonferroni corrections, the results remained the same as reported in the main text, except that the father spatial tokens × child gender interaction was no longer significant ($p = .102$).

RR = 2.01) and the card game (estimated marginal $M = 2.10$, $SE = 0.09$, adjusted $p < .001$, Etch-a-Sketch vs. card game $RR = 1.92$).

These results showed that different task types elicited different amount of parental spatial language (both tokens and types), with the Etch-a-Sketch task leading to the most spatial language, nearly two to three times as much as those in the block task and the card game. However, parents' use of spatial language did not differ between boys and girls.[6]

Figure 1

Counts of Parental Praise Instances, Spatial Tokens, and Spatial Types per Minute in Different Tasks, Separately by Parent Sex

[6] We also considered whether the differences in parent support per minute might have been driven by differences in overall language per minute in each task. To address this and as a robustness check, we conducted Poisson log linear GEE models on parent support variables while accounting for total parental language, by using the percentage of praise or spatial language out of total parental language as the DV. The results were very similar to our main analyses in that parents' support was consistently lowest in the card game, although there were some differences in whether parents' support was higher in the Etch-a-Sketch or block task. Specifically, for the percentage of praise out of total utterances, fathers had higher praise percentages in both the Etch-a-Sketch task and the block task than the card game, whereas mothers had the highest praise percentage in the block task, then in the Etch-a-Sketch task, and lowest in the card game (*p*s < .001). For the percentage of spatial tokens out of total speech tokens, both fathers and mothers had the highest spatial token percentage in the Etch-a-Sketch task, then in the block task, and lowest in the card game (*p*s < .001). The percentage of spatial types out of total speech types shared the same pattern as spatial tokens.

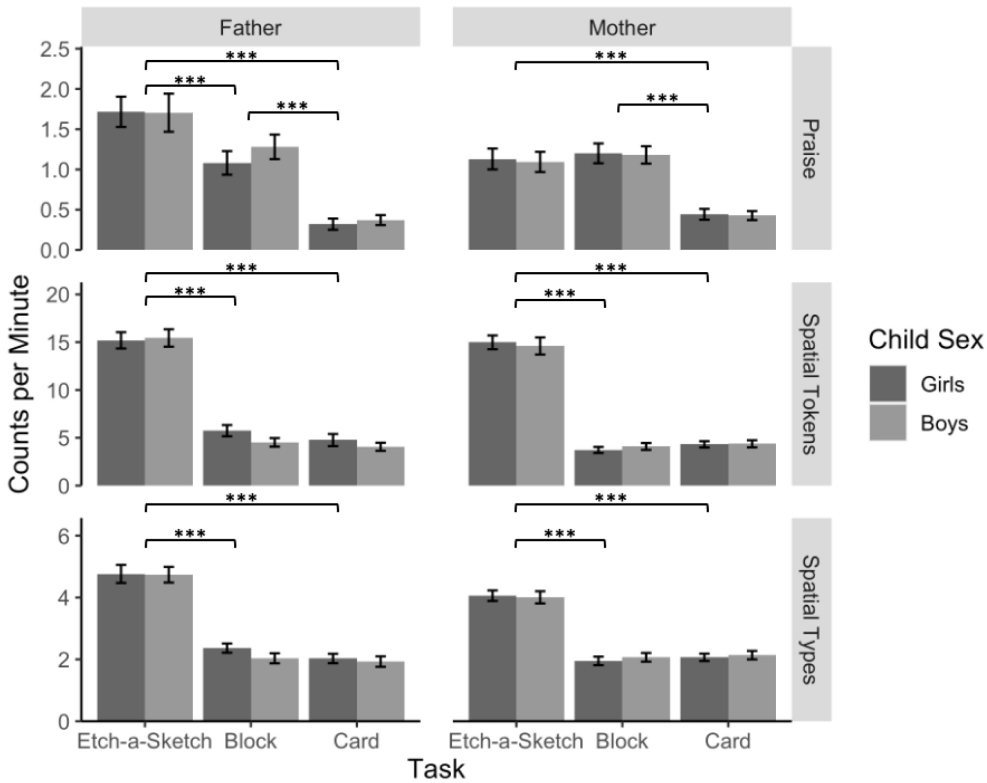

Father
Mother
Praise
Spatial Tokens
Spatial Types
Counts per Minute
Task
Etch-a-Sketch
Block
Card
Child Sex
Girls
Boys
***

Table 1

Generalized Estimating Equation Models With Parental Praise and Spatial Language as Outcomes, Separately by Parent Sex

Variables	Model 1 father praise		Model 2 mother praise		Model 3 father spatial tokens		Model 4 mother spatial tokens		Model 5 father spatial types		Model 6 mother spatial types	
	$\chi^2(df)$	*p*	$\chi^2(df)$	*p*	$\chi^2(df)$	*p*	$\chi^2(df)$	*p*	$\chi^2(df)$	*p*	$\chi^2(df)$	*p*
Child Sex	0.42 (1)	.516	0.06 (1)	.802	1.82 (1)	.178	0.12 (1)	.733	1.07 (1)	.300	0.20 (1)	.657
Task Type	127.84 (2)	<.001	83.21 (2)	<.001	303.36 (2)	<.001	716.45 (2)	<.001	223.39 (2)	<.001	263.11 (2)	<.001
Child Sex × Task Type	0.86 (2)	.650	0.01 (2)	.994	2.97 (2)	.226	0.99 (2)	.609	1.64 (2)	.441	0.55 (2)	.759

Did Parental Praise and Spatial Language Have Additive Relations to Children's Math Achievement and Spatial Skills?

Third-Grade Math Achievement

We first regressed 3rd-grade math achievement on paternal and maternal praise and spatial tokens (Table 2, Model 1). Results showed that the prior 1st-grade math achievement was significant in the model with spatial tokens, $\beta = .66$, $SE = .10$, $p < .001$, but the other variables were not significant (*p*s ≥ .299). We then regressed math achievement on praise and spatial types. Similarly, 1st-grade math achievement was significantly related to 3rd-grade math, $\beta = .67$, $SE = .10$, $p < .001$ (Table 2, Model 2). However, the other variables were not significant (*p*s ≥ .088). Full models with covariates are shown in Supplemental Table S2.

Fourth-Grade Spatial Skills

Regressions examining 4th-grade spatial skills using parental spatial tokens showed that children's 2-year-old mental development level was positively related to their spatial skills, $\beta = .35$, $SE = .11$, $p = .002$ (Table 2, Model 3). The other variables were not significant after Bonferroni corrections (ps $\geq .003$). Regarding the regression using spatial types (Table 2, Model 4), child sex was significantly associated with spatial skills, $\beta = .62$, $SE = .19$, $p = .001$. Children's 2-year-old mental development level was also positively related to their spatial skills, $\beta = .37$, $SE = .11$, $p = .001$, but the other variables were not significant (ps $\geq .008$). Full model results including covariates are shown in Supplemental Table S2.

Table 2

Linear Regressions With Children's Math and Spatial Outcomes (N = 107)

Variables	3rd-grade math achievement		4th-grade spatial skills	
	Model 1	Model 2	Model 3	Model 4
	Standardized parameter estimate (*SE*)			
1st-grade math achievement	.66 (.10)*	.67 (.10)*	.31 (.11)	.29 (.11)
Child sex (reference: female)	-.07 (.17)	-.09 (.17)	.58 (.20)	.62 (.19)*
Paternal praise	.13 (.12)	.11 (.12)	-.02 (.13)	-.08 (.13)
Maternal praise	-.07 (.10)	-.07 (.09)	.05 (.11)	.04 (.11)
Paternal spatial tokens	-.08 (.12)		.09 (.12)	
Maternal spatial tokens	-.02 (.10)		-.15 (.11)	
Paternal spatial types		.09 (.10)		.13 (.12)
Maternal spatial types		-.15 (.09)		.00 (.10)
Covariates included	Yes	Yes	Yes	Yes

Note. Praise and spatial language were calculated by using the raw count of language variables divided by duration of time, square-root transformed. Covariates in all models were maternal education, family income-to-needs ratio, maternal partner status, 2-year-old child's mental development, child race, paternal and maternal cognitive stimulation.

* $p < .003$.

Did Parental Praise and Spatial Language Have Multiplicative Relations to Children's Math Achievement and Spatial Skills?

We first examined the interaction between paternal praise and spatial language, as well as the interaction between maternal praise and spatial language, in relation to children's math and spatial outcomes. We conducted separate models with spatial types and spatial tokens as predictors, for four total models. None of the interaction terms were significant in any model after Bonferroni corrections (*p*s $\geq .044$). Full model results are shown in Supplemental Table S3.

Did Maternal and Paternal Support Have Multiplicative Relations to Children's Math Achievement and Spatial Skills?

We next examined the interaction between paternal praise and maternal praise, along with the interaction between paternal spatial language and maternal spatial language predicting 3rd grade math achievement and 4th grade spatial skills (four total models, shown in Supplemental Table S4). No interaction terms were significant after Bonferroni corrections (ps $\geq .012$).

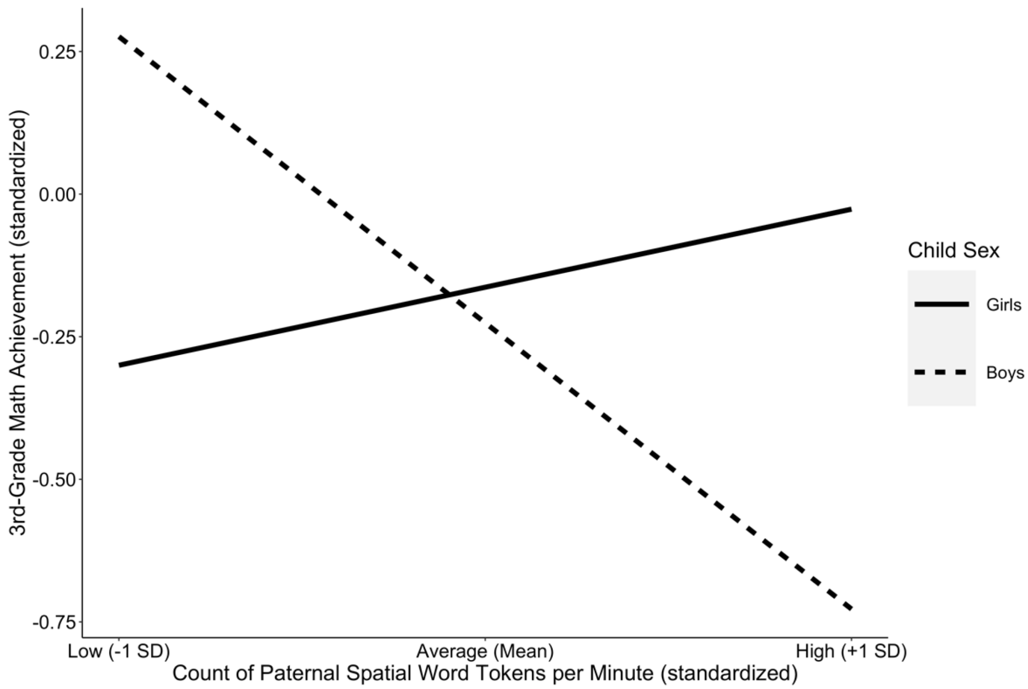
Did Parental Support Have Different Relations to Boys' and Girls' Math Achievement and Spatial Skills?

Third-Grade Math Achievement

We first examined the interactions of Parent Spatial Language × Child Sex and Parent Praise × Child Sex with math achievement as the outcome. For spatial tokens, the interaction between paternal spatial tokens and child sex was significant, $\beta = -.65$, $SE = .20$, $p = .001$ (see Figure 2), suggesting that paternal cognitive support had different relations to boys' and girls' math achievement. The simple slope of paternal cognitive support for boys was significantly negative, $\beta = -.50$, $SE = .17$, $p = .003$, but the simple slope for girls was not significant, $\beta = .14$, *SE* = .13, *p* = .305. For spatial types, the interaction terms were not significant (ps ≥ .174). Full model results are shown in Supplemental Table S5.

Figure 2

The Interaction Between Child Sex and Paternal Spatial Language in Relation to 3rd-Grade Math Achievement



Fourth-Grade Spatial Skills

Finally, we examined the interactions of Parent Spatial Tokens × Child Sex and Parent Praise × Child Sex with 4th-grade spatial skill as the outcome. However, no interaction terms were significant (ps ≥ .102). Full models with covariates are shown in Supplemental Table S5.

Discussion

Our study examined the pattern of paternal and maternal praise and spatial language during parent-child interactions and the relations between this support and children's math achievement in 3rd grade and spatial skill in 4th grade. We found that different tasks were related to different amounts of praise and spatial language from parents, whereas child sex did not relate to parents' support. We also found that higher paternal spatial word tokens were associated with *lower* 3rd-grade math achievement in boys, but not in girls. We discuss each of our findings in detail below.

The Pattern of Parental Praise and Spatial Language

The first aim of this study was to understand whether parental support varied between different tasks and child sex. The results showed that parents gave more praise to children in the Etch-a-Sketch task and the block task than in the card game. This pattern was largely consistent across fathers and mothers, except that fathers gave more praise in the Etch-a-Sketch task than the block task, whereas mothers did not show this difference. This is the first study, to our knowledge, to reveal task differences in parental praise to school-age children, and to show the pattern from both fathers and mothers. One possible explanation for the effect of task on parents' praise is that when parents share the same goal with children, they pay more attention to motivating children to achieve the goal (as in the Etch-a-Sketch and block tasks), whereas when they held opposite goals (in the competitive card game), parents were less likely to use praise to motivate children as children may already be motivated by the nature of competition. Another possibility is that goal-directed tasks that involve many concrete steps, such as drawing lines to form a picture or placing blocks to form a pattern, offer many opportunities for praise at intermediate points in the process. Consistent with these explanations, one study of infants reported that parents praised their one-year-olds more when playing with puzzles and shape sorters - both collaborative goal-directed activities with many intermediate steps - than when playing with trucks and kitchen toys (Caldera et al., 1989). Future research that systematically varies task features, such as the goal of a task (collaborative versus competitive) and the number of intermediate steps, will be important for understanding how these task features elicit different amounts of parental praise.

Additionally, parents produced more spatial language (both tokens and types) in the Etch-a-Sketch task than in the other two tasks. This finding of high spatial language usage during an Etch-a-Sketch task is novel, given that previous relevant studies have primarily focused on blocks and puzzles. It is possible that parents might be more involved in the Etch-a-Sketch task than the other tasks because the task itself required them to cooperate with the child by simultaneously moving the knobs of the Etch-a-Sketch along with their child. It is possible that the cooperative nature of the task led to more spatial language along the way to achieve the goal.

In terms of child sex, we did not find that parents gave different amounts of praise and spatial language to boys compared to girls, inconsistent with some prior findings (Gunderson et al., 2013; Levine et al., 2012; Pruden & Levine, 2017; Ralph et al., 2021). There are three possible reasons for this inconsistency. First, the current study included broader categories when measuring parental praise and spatial language. Specifically, we used the summation of process praise and other praise to index parental praise, whereas Gunderson et al. (2013) only examined process praise. To check if different praise variables led to different results across the two studies, we examined whether child sex affected parental process praise only (Footnote 3). We found no significant difference in parents' process praise to boys than to girls, suggesting that there might be other factors causing this inconsistency. Regarding parental spatial language, we included all the categories of spatial language identified in Cannon et al. (2007), whereas most prior studies on spatial language have focused on different sub-categories. For example, Pruden and Levine (2017) included shape, dimension, and spatial feature terms as their measure of spatial language. We included all the categories because we did not have any strong prior hypotheses on the specific effect of certain categories in the three tasks of the current study. Even though these results are not readily comparable, our findings still shed light on the patterns of fathers' and mother' support in boys and girls.

Second, the current study examined children who had already entered formal schooling, unlike prior studies that focused on parent-child interactions with much younger children. It is possible that parents may provide different amounts of support to boys and girls before they start the formal education. In 1st-grade children from a different site of the SECCYD dataset, Thomson et al. (2020) did not find a significant relation between child sex and fathers' production of spatial language (specifically language about spatial locations) in the block task, consistent with current findings. In addition, the current study also examined different tasks with both parents, which further contributed to understanding patterns of parental support in boys and girls after formal schooling. Third, prior studies that showed sex differences were conducted in free-play parent-child interactions. For example, in both Gunderson et al. (2013) and Pruden and Levine (2017), each parent-child dyad had different choices of activities. Though Ralph et al. (2021) provided a set of magnetic tile toys, parent and child were still allowed to play freely. As mentioned above, the present study observed parent-child interactions using the same set of play materials with the same set goals for each dyad. This may have led parents to show similar patterns of support across child sex. Altogether, current findings highlighted that for 1st-grade children, the level of parental praise and spatial language might be more dependent on the type of task than on child sex. Future studies would benefit in longitudinally following parent-child interactions with different task features and play materials, before and after children start formal schooling, to further disentangle factors that affect parental support.

Relations Between Parental Support and Children's Math Achievement

The second aim of our study was to examine the role of parental support during spatial tasks for potentially additive or multiplicative relations to children's later math and spatial skills. Unexpectedly, we did not find any direct and additive relations of parents' support when accounting for children's current math achievement, support from the other parent, parental general cognitive stimulation, and other child and family covariates. We also did not find evidence supporting multiplicative relations between parental support and children's spatial skills and math achievement. The lack of direct relations between parents' support and children's outcomes was consistent with Thomson et al. (2020), which did not find significant relations between fathers' quantitatively measured spatial language and children's 1st-grade math achievement.

One possible reason that we didn't find direct relations is that children have started formal schooling and the school environment (e.g., teacher-child relationship and classroom quality) might have an increasing impact on children's cognitive development. Prior work using the SECCYD dataset has shown positive associations between quality of teacher-child relationships and children's' math and verbal achievement in 3rd grade (O'Connor & McCartney, 2007). Although examining the impact of teachers' support was outside the scope of the current study, we encourage future work to consider the impact of both family and school in building a supportive environment for children's development.

The consistency between our results and Thomson et al. (2020) also brings up another possibility, which is that the kinds of cognitive support we captured by examining spatial language in parent-child interactions when children were in 1st grade might not be the most promotive of children's spatial skill development at this age. For example, the broad categories of spatial language may not be sensitive enough to present its advantageous role in children's development. Children at 1st-grade age may benefit from more advanced spatial talk that targets mental rotation and geometric properties (e.g., talk involving 2-D transformation and geometric embedded shapes), as these spatial abilities are under development at this age (e.g., Carr et al., 2018; Crescentini et al., 2014) and have shown great potential for enhancing children's spatial and math abilities (e.g., Hawes et al., 2017). Therefore, future studies should consider distinguishing between advanced and basic spatial language (similar to work distinguishing advanced versus foundational number talk, e.g., Ramani et al., 2015) and identifying distinct roles of different types of spatial language at different ages.

Further, our analyses exploring child sex differences demonstrated that the interaction between parental support and child sex was significantly related to children's later math achievement. Specifically, fathers' production of spatial tokens had different relations to children's later math achievement for boys and for girls. For boys, more spatial tokens from their father were associated with *lower* 3rd-grade math achievement. For girls, the relation between fathers' spatial tokens and later math achievement was positive but not significant. Although this negative relation for boys was unexpected, it is consistent with a previous study which found that parents' numeracy talk during Lego building was negatively associated with children's calculation performance (Yildiz et al., 2018). This might be explained by self-determination theory (Deci & Ryan, 1985), where more fathers' spatial tokens were perceived as intrusive to boys and restrained boys' autonomy because of their possibly more autonomous learning style (Kimball, 1989) and their greater benefit from independent explorations (Newcombe, 1982; Sherman, 1967). This lack of support for autonomy may further hinder boys' skill development. The negative correlation between fathers' spatial tokens and fathers' respect for children's autonomy also lends some support for this possibility (see Footnote 2).

It is also possible that fathers' provision of spatial tokens reflected fathers' additional effort to help boys with lower abilities (Saxe et al., 1987). This explanation is consistent with our findings of a negative correlation between fathers' spatial tokens and children's mental development at 2 years old and 1st-grade math achievement. Though it is not clear why this relation was not significant among girls, our results demonstrated that a higher quantity of spatial language was not always beneficial to boys. The fact that this negative relation of fathers' spatial language to boys' later math achievement was found when examining spatial tokens, but not spatial types, is consistent with the idea that word types (i.e., diversity of words) are more indicative high-quality parental support than word tokens (frequency of words) (Rowe, 2012). Future research is clearly needed to investigate the impact of parental support in boys and girls when they are at different ages and cognitive development levels, to identify the right amounts and types of support that are beneficial to children.

Limitations and Future Directions

The current study extended upon prior literature to examine the pattern of parents' praise and spatial language and their joint impacts on children's math and spatial skills, with some limitations. First, we were not able to directly compare whether parental support differed by parent sex because fathers and mothers completed slightly different tasks with their children, confounding task with parent sex. This was because the tasks were originally designed to measure general quality of parent interactions across a variety of challenging tasks, rather than to equate father- and mother-child interactions. Specifically, fathers and mothers drew different pictures in the Etch-a-Sketch task, played card games with distinct rules, and additionally, children did a 3-D cube block building task with their fathers, whereas children did a 2-D pattern block task with their mothers. Additionally, father-child interactions happened in the home environment, whereas mother-child interactions happened in the lab setting. This may have impacted the nature of these interactions, as parents and children might feel more comfortable at home than in the lab. Indeed, a recent study found that parent number talk at home was not related to their number talk in the lab (Thippana et al., 2020). The present research provided the general framework to study fathers' and mothers' varied aspects of support in different tasks, inspiring future research to systematically control the play materials and interaction environment so as to directly compare father- and mother-child interactions.

Another potential limitation is that, in our analyses of the relations between parental support and children's 3rd-grade math achievement and 4th-grade spatial skills, children's 1st-grade math achievement was always a significant variable. It is possible that children's skill development was less dependent on parental support after they began formal schooling. This finding points to the importance of examining parental support for children's skill development at earlier ages. Although other researchers have examined parental support at earlier ages, (Borriello & Liben, 2018; Pruden & Levine, 2017; Ralph et al., 2021), these previous studies focused on one parent only. Thus, it would be fruitful for future studies to investigate parent-child interactions with both fathers and mothers prior to the onset of formal schooling.

In addition, broad societal changes in the fathers' roles should be taken into account when considering these results and their implications for future research. The parent-child interactions in our study took place in the late 1990s, at which time fathers were still considered by most people to be the main breadwinner, leaving the responsibility for taking care of children largely to mothers (for a review, see Cabrera et al., 2000). In the decades since then, maternal employment rates have increased, and the more mothers earn relative to their husbands, the more likely fathers are to take on greater childcare responsibilities and spend quality time interacting with their children (for a review, see Cabrera et al., 2018). Therefore, it would be productive for future research to explore today's parenting roles and whether these societal changes impact the relations between maternal and paternal support and children's development.

Relatedly, our analyses did not examine whether the typical amount of time spent interacting with each parent impacted the association between parent support and children's outcomes. Some prior work in the domain of emotional adjustment suggests that more time spent with children is related to stronger effects of parent quality on child outcomes (Van Lissa & Keizer, 2020). It is plausible that the relations we investigated would be stronger for parents who spend more time with their children in similar interactions to those we observed; this may vary depending on parenting roles, parents' overall time spent in one-on-one interactions at home, propensity to engage with their children in spatial activities, and other factors.

Further, it is important to emphasize that all the analyses with children's math and spatial outcomes in the current study were correlational. Though the longitudinal design and strong set of control variables can move us closer to understanding the impact of parental support, we still cannot firmly establish a causal direction nor can we rule out the contributions of other unmeasured factors that are associated with children's math and spatial development. Future research is needed to establish strong causal relations between parental different aspects of support and children's math and spatial development. A related limitation is that the sample size for our extensive analyses is relatively small, leading to limited power to detect small effects. Though we utilized Bonferroni correction to control family-wise error rate, future studies with larger sample size are warranted.

Lastly, the SECCYD sample had higher household income and maternal education level than the U.S. average, though sample families were more likely to receive public assistance than U.S families in general (NICHD Early Child Care Research Network, 2001). Moreover, the study involved participants from an Eastern U.S. city whose children primarily identified as either White (72.0%) or Black (23.4%). Though child ethnicity was included in our models, having to combine other ethnic minority groups magnified the demographic limitations of this sample. Given that prior studies have shown that parents of different ethnic group interacted differently with their children (e.g., Suh et al., 2019), these limitations further warrant more research to understand whether and how other family factors contribute to parental support that can lead to gains in children's development

Conclusion

The current study extends upon prior literature regarding the impact of parental support on children's math and spatial skills to investigate both parental praise and spatial language from both fathers and mothers. Both parents gave more praise in spatial activities (the Etch-a-Sketch task and the block task) than in the card game, and both parents provided more spatial language in the Etch-a-Sketch task than in the other tasks. However, we did not find any child sex differences in parents' support, suggesting that sex differences in parents' praise and spatial language in prior research may be explained by sex differences in parents' and children's choices of tasks, which in turn may have elicited different amounts of praise and spatial language. We also found that fathers' greater spatial language was related to boys' (but not girls') lower math achievement. This finding indicates that more spatial language from parents is not always better, and in fact might be associated with lower math achievement at this age. Future research is warranted to establish causal relations between parental support and children's development and to uncover the cause of the negative relation found in boys. Altogether, our findings shed further light on our understanding of parents' cognitive and motivational support in promoting children's skill development and provide insights into identifying strategies for parents to be supportive but not intrusive in parent-child interactions.

References

Acock, A. C. (2012). What to do about missing values. In *APA handbook of research methods in psychology, Vol 3: Data analysis and research publication* (pp. 27–50). American Psychological Association. https://doi.org/10.1037/13621-002

Bayley, N. (1993). *Bayley scales of infant development: Second edition (standardization version)*. The Psychological Corporation.

Bjorklund, D., Hubertz, M., & Reubens, A. (2004). Young children's arithmetic strategies in social context: How parents contribute to children's strategy development while playing games. *International Journal of Behavioral Development*, *28*(4), 347–357. https://doi.org/10.1080/01650250444000027

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*(1), 246–263. https://doi.org/10.1111/j.1467-8624.2007.00995.x

Borriello, G. A., & Liben, L. S. (2018). Encouraging maternal guidance of preschoolers' spatial thinking during block play. *Child Development*, *89*(4), 1209–1222. https://doi.org/10.1111/cdev.12779

Bradley, R. H., Iida, M., Pennar, A., Owen, M. T., & Vandell, D. L. (2017). The dialectics of parenting: Changes in the interplay of maternal behaviors during early and middle childhood. *Journal of Child and Family Studies*, *26*(11), 3214–3225. https://doi.org/10.1007/s10826-017-0805-6

Brummelman, E., Crocker, J., & Bushman, B. J. (2016). The praise paradox: When and why praise backfires in children with lowsdelf-esteem. *Child Development Perspectives*, *10*(2), 111–115. https://doi.org/10.1111/cdep.12171

Brummelman, E., Thomaes, S., Orobio de Castro, B., Overbeek, G., & Bushman, B. J. (2014). "That's Not Just Beautiful—That's Incredibly Beautiful!": The Adverse Impact of Inflated Praise on Children With Low Self-Esteem. *Psychological Science*, *25*(3), 728–735. https://doi.org/10.1177/0956797613514251

Brummelman, E., Thomaes, S., Overbeek, G., Orobio de Castro, B., van den Hout, M. A., & Bushman, B. J. (2014). On feeding those hungry for praise: Person praise backfires in children with low self-esteem. *Journal of Experimental Psychology: General*, *143*(1), 9–14. https://doi.org/10.1037/a0031917

Cabrera, N. J., Shannon, J. D., & Tamis-lemonda, C. (2007). Fathers' influence on their children's cognitive and emotional development: From toddlers to pre-K. *Applied Development Science*, 208–213.

Cabrera, N. J., Tamis-LeMonda, C. S., Bradley, R. H., Hofferth, S., & Lamb, M. E. (2000). Fatherhood in the twenty-first century. *Child Development*, *71*(1), 127–136. https://doi.org/10.1111/1467-8624.00126

Cabrera, N. J., Volling, B. L., & Barr, R. (2018). Fathers are parents, too! Widening the lens on parenting for children's development. *Child Development Perspectives*, *12*(3), 152–157. https://doi.org/10.1111/cdep.12275

Caldera, Y. M., Culp, A. M., O'Brien, M., Truglio, R. T., Alvarez, M., & Huston, A. C. (1999). Children's play preferences, construction play with blocks, and visual-spatial skills: Are they related? *International Journal of Behavioral Development*, *23*(4), 855–872. https://doi.org/10.1080/016502599383577

Caldera, Y. M., Huston, A. C., & O'Brien, M. (1989). Social Interactions and Play Patterns of

Parents and Toddlers with Feminine, Masculine, and Neutral Toys. *Child Development*, *60*(1), 70–76. https://doi.org/10.2307/1131072

Cannon, J., Levine, S. C., & Huttenlocher, J. (2007). *A system for analyzing children and caregivers' language about space in structured and unstructured contexts.* [Spatial Intelligence and Learning Center (SILC) technical report.].

Carr, M., Alexeev, N., Wang, L., Barned, N., Horan, E., & Reed, A. (2018). The development of spatial skills in elementary school students. *Child Development*, *89*(2), 446–460. https://doi.org/10.1111/cdev.12753

Casey, B. M., Dearing, E., Dulaney, A., Heyman, M., & Springer, R. (2014). Young girls' spatial and arithmetic performance: The mediating role of maternal supportive interactions during joint spatial problem solving. *Early Childhood Research Quarterly*, *29*(4), 636–648. https://doi.org/10.1016/j.ecresq.2014.07.005

Casey, B. M., Lombardi, C. M., Thomson, D., Nguyen, H. N., Paz, M., Theriault, C. A., & Dearing, E. (2016). Maternal support of children's early numerical concept learning predicts preschool and first-grade math achievement. *Child Development*, *89*(1), 156–173. https://doi.org/10.1111/cdev.12676

Chan, J. Y.-C., Praus-Singh, T. L., & Mazzocco, M. M. M. (2020). Parents' and young children's attention to mathematical features varies across play materials. *Early Childhood Research Quarterly*, *50*, 65–77. https://doi.org/10.1016/j.ecresq.2019.03.002

Clarke-Stewart, K. A. (1978). And Daddy makes three: The father's impact on mother and young child. *Child Development*, *49*(2), 466–478. https://doi.org/10.2307/1128712

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*. https://doi.org/10.1177/001316446002000104

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J: L. Erlbaum Associates.

Cook, G. A., Roggman, L. A., & Boyce, L. K. (2011). Fathers' and mothers' cognitive stimulation in early play with toddlers: Predictors of 5th grade reading and math. *Family Science*, *2*(2), 131–145. https://doi.org/10.1080/19424620.2011.640559

Crescentini, C., Fabbro, F., & Urgesi, C. (2014). Mental spatial transformations of objects and bodies: Different developmental trajectories in children from 7 to 11 years of age. *Developmental Psychology*, *50*(2), 370–383. https://doi.org/10.1037/a0033627

Datavyu Team. (2014). Datavyu: A video coding tool. *Databrary Project, New York University. URL Http://Datavyu. Org*.

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality*, *19*(2), 109–134. https://doi.org/10.1016/0092-6566(85)90023-6

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review*, *95*(2), 256–273. https://doi.org/10.1037/0033-295X.95.2.256

Eason, S. H., & Ramani, G. B. (2020). Parent–child math talk about fractions during formal learning and guided play activities. *Child Development*, *91*(2), 546–562. https://doi.org/10.1111/cdev.13199

Eisner, N. L., Murray, A. L., Eisner, M., & Ribeaud, D. (2019). A practical guide to the analysis of non-response and attrition in longitudinal research using a real data example. *International Journal of Behavioral Development*, *43*(1), 24–34. https://doi.org/10.1177/0165025418797004

Erikson, E. H. (1970). Autobiographic notes on the identity crisis. *Daedalus*, *99*(4), 730–759.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Ferrara, K., Hirsh-Pasek, K., Newcombe, N. S., Golinkoff, R. M., & Lam, W. S. (2011). Block talk: Spatial language during block play. *Mind, Brain, and Education*, *5*(3), 143–151. https://doi.org/10.1111/j.1751-228X.2011.01122.x

Frome, P. M., & Eccles, J. S. (1998). Parents' influence on children's achievement-related perceptions. *Journal of Personality and Social Psychology*, *74*(2), 435–452. https://doi.org/10.1037/0022-3514.74.2.435

Grolnick, W. S., & Slowiaczek, M. L. (1994). Parents' involvement in children's schooling: A multidimensional conceptualization and motivational model. *Child Development*, *65*(1), 237–252. https://doi.org/10.2307/1131378

Gunderson, E. A., Gripshover, S. J., Romero, C., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2013). Parent praise to 1- to 3-year-olds predicts children's motivational frameworks 5 years later. *Child Development*, *84*(5), 1526–1541. https://doi.org/10.1111/cdev.12064

Gunderson, E. A., Sorhagen, N. S., Gripshover, S. J., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2018). Parent praise to toddlers predicts fourth grade academic achievement via children's incremental mindsets. *Developmental Psychology*, *54*(3), 397–409. https://doi.org/10.1037/dev0000444

Hawes, Z., Moss, J., Caswell, B., Naqvi, S., & MacKinnon, S. (2017). Enhancing Children's Spatial and Numerical Skills through a Dynamic Spatial Approach to Early Geometry

Instruction: Effects of a 32-Week Intervention. *Cognition and Instruction*, *35*(3), 236–264. https://doi.org/10.1080/07370008.2017.1323902

Højsgaard, S., Halekoh, U., & Yan, J. (2005). The R Package geepack for Generalized Estimating Equations. *Journal of Statistical Software*, *15*(1), 1–11. https://doi.org/10.18637/jss.v015.i02

Hong, Y., Chiu, C., Dweck, C. S., Lin, D. M.-S., & Wan, W. (1999). Implicit theories, attributions, and coping: A meaning system approach. *Journal of Personality and Social Psychology*, *77*(3), 588–599. https://doi.org/10.1037/0022-3514.77.3.588

Jirout, J. J., & Newcombe, N. S. (2015). Building blocks for developing spatial skills: Evidence from a large, representative U.S. sample. *Psychological Science*, *26*(3), 302–310. https://doi.org/10.1177/0956797614563338

John, A., Halliburton, A., & Humphrey, J. (2013). Child–mother and child–father play interaction patterns with preschoolers. *Early Child Development and Care*, *183*(3–4), 483–497. https://doi.org/10.1080/03004430.2012.711595

Kamins, M. L., & Dweck, C. S. (1999). Person versus process praise and criticism: Implications for contingent self-worth and coping. *Developmental Psychology*, *35*(3), 835–847. https://doi.org/10.1037/0012-1649.35.3.835

Kimball, M. M. (1989). A new perspective on women's math achievement. *Psychological Bulletin*, *105*(2), 198–214. https://doi.org/10.1037/0033-2909.105.2.198

Lee, J., & Wood, E. (2020). Examining parent–child spatial play interaction using traditional toys and touch screen tablets. *Parenting*, *0*(0), 1–28. https://doi.org/10.1080/15295192.2020.1811062

Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early puzzle play: A predictor of preschoolers' spatial transformation skill. *Developmental Psychology*, *48*(2), 530–542. https://doi.org/10.1037/a0025913

Liang, K.-Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika*, *73*(1), 13–22. JSTOR. https://doi.org/10.2307/2336267

Lombardi, C. M., Casey, B. M., Thomson, D., Nguyen, H. N., & Dearing, E. (2017). Maternal support of young children's planning and spatial concept learning as predictors of later math (and reading) achievement. *Early Childhood Research Quarterly*, *41*, 114–125. https://doi.org/10.1016/j.ecresq.2017.07.004

Martin, A., Ryan, R. M., & Brooks-Gunn, J. (2007). The joint influence of mother and father parenting on child cognitive outcomes at age 5. *Early Childhood Research Quarterly*, *22*(4), 423–439. https://doi.org/10.1016/j.ecresq.2007.07.001

Martin, A., Ryan, R. M., & Brooks-Gunn, J. (2010). When fathers' supportiveness matters most: Maternal and paternal parenting and children's school readiness. *Journal of Family Psychology*, *24*(2), 145–155. https://doi.org/10.1037/a0018073

McGrew, K. S., Werder, J. K., & Woodcock, R. W. (1991). *WJ-R technical manual*. DLM.

Morris, B. J., & Zentall, S. R. (2014). High fives motivate: The effects of gestural and ambiguous verbal praise on motivation. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00928

Newcombe, N. S. (1982). Sex-related differences in spatial ability: Problems and gaps in current approaches. In M. Potegal (Ed.), *Spatial abilities: Development and physiological foundations* (pp. 223–250). Academic Press.

Newcombe, N. S., Booth, J. L., & Gunderson, E. A. (2019). Spatial skills, reasoning, and mathematics. In *The Cambridge handbook of cognition and education* (pp. 100–123).

Cambridge University Press. https://doi.org/10.1017/9781108235631.006

NICHD Early Child Care Research Network. (2001). Nonmaternal care and family factors in early development: An overview of the NICHD Study of Early Child Care. *Journal of Applied Developmental Psychology*, *22*(5), 457–492. https://doi.org/10.1016/S0193-3973(01)00092-2

O'Connor, E., & McCartney, K. (2007). Examining teacher–child relationships and achievement as part of an ecological model of development. *American Educational Research Journal*, *44*(2), 340–369. https://doi.org/10.3102/0002831207302172

Park, D., Gunderson, E. A., Tsukayama, E., Levine, S. C., & Beilock, S. L. (2016). Young children's motivational frameworks and math achievement: Relation to teacher-reported instructional practices, but not teacher theory of intelligence. *Journal of Educational Psychology*, *108*(3), 300–313. https://doi.org/10.1037/edu0000064

Pianta, R. C., & Rimm-Kaufman, S. (2006). The social ecology of the transition to school: Classrooms, families, and children. In *Blackwell handbook of early childhood development* (pp. 490–507). Blackwell Publishing. https://doi.org/10.1002/9780470757703.ch24

Pruden, S. M., & Levine, S. C. (2017). Parents' spatial language mediates a sex difference in preschoolers' spatial language use. *Psychological Science*, *28*(11), 1583–1596. https://doi.org/10.1177/0956797617711968

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science*, *14*(6), 1417–1430. https://doi.org/10.1111/j.1467-7687.2011.01088.x

Psychological Corporation. (1999). *Wechsler abbreviated scale of intelligence*. Harcourt Brace

& Company, San Antonio, TX.

R Core Team. (2020). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing. https://www.R-project.org/

Ralph, Y. K., Berinhout, K., & Maguire, M. J. (2021). Gender differences in mothers' spatial language use and children's mental rotation abilities in Preschool and Kindergarten. *Developmental Science*, *24*(2), e13037. https://doi.org/10.1111/desc.13037

Ramani, G. B., Rowe, M. L., Eason, S. H., & Leech, K. A. (2015). Math talk during informal learning activities in Head Start families. *Cognitive Development*, *35*, 15–33. https://doi.org/10.1016/j.cogdev.2014.11.002

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(1), 1–36. https://doi.org/10.18637/jss.v048.i02

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*(5), 1762–1774. https://doi.org/10.1111/j.1467-8624.2012.01805.x

Saxe, G. B., Guberman, S. R., Gearhart, M., Gelman, R., Massey, C. M., & Rogoff, B. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development*, *52*(2), i–162. JSTOR. https://doi.org/10.2307/1166071

Sherman, J. A. (1967). Problem of sex differences in space perception and aspects of intellectual functioning. *Psychological Review*, *74*(4), 290–299. https://doi.org/10.1037/h0024723

Suh, D. D., Liang, E., Ng, F. F.-Y., & Tamis-LeMonda, C. S. (2019). Children's block-building skills and mother-child bock-building interactions across four U.S. ethnic groups. *Frontiers in Psychology*, *10*, 1626. https://doi.org/10.3389/fpsyg.2019.01626

Tamis-LeMonda, C. S., Shannon, J. D., Cabrera, N. J., & Lamb, M. E. (2004). Fathers and mothers at play with their 2- and 3-year-olds: Contributions to language and cognitive development. *Child Development*, *75*(6), 1806–1820. https://doi.org/10.1111/j.1467-8624.2004.00818.x

Thippana, J., Elliott, L., Gehman, S., Libertus, K., & Libertus, M. E. (2020). Parents' use of number talk with young children: Comparing methods, family factors, activity contexts, and relations to math skills. *Early Childhood Research Quarterly*, *53*, 249–259. https://doi.org/10.1016/j.ecresq.2020.05.002

Thomson, D., Casey, B. M., Lombardi, C. M., & Nguyen, H. N. (2020). Quality of fathers' spatial concept support during block building predicts their daughters' early math skills – but not their sons'. *Early Childhood Research Quarterly*, *50*, 51–64. https://doi.org/10.1016/j.ecresq.2018.07.008

Tzuriel, D., & Egozi, G. (2010). Gender differences in spatial ability of young children: The effects of training and processing strategies. *Child Development*, *81*(5), 1417–1430. https://doi.org/10.1111/j.1467-8624.2010.01482.x

U.S. Department of Health and Human Services. (2018a). *NICHD Study of Early Child Care and Youth Development: Phase I, 1991-1994 [United States]* (ICPSR 21940) [Data set]. https://www.icpsr.umich.edu/web/ICPSR/studies/21940

U.S. Department of Health and Human Services. (2018b). *NICHD Study of Early Child Care and Youth Development: Phase II, 1995-1999 [United States]* (ICPSR 21941) [Data set]. https://www.icpsr.umich.edu/web/ICPSR/studies/21941

U.S. Department of Health and Human Services. (2018c). *NICHD Study of Early Child Care and Youth Development: Phase III, 2000-2004 [United States]* (ICPSR 21942) [Data set]. https://www.icpsr.umich.edu/web/ICPSR/studies/21942

Van Lissa, C. J., & Keizer, R. (2020). Mothers' and fathers' quantitative and qualitative parenting in relation to children's emotional adjustment: A between- and within-family investigation. *Developmental Psychology*, *56*(9), 1709–1722. https://doi.org/10.1037/dev0001042

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematical skills. *Child Development*, *85*(3), 1062–1076. https://doi.org/10.1111/cdev.12165

Verdine, B. N., Zimmermann, L., Foster, L., Marzouk, M. A., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2019). Effects of geometric toy design on parent–child interactions and spatial language. *Early Childhood Research Quarterly*, *46*, 126–141. https://doi.org/10.1016/j.ecresq.2018.03.015

Vygotsky, L. S. (1980). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817–835. https://doi.org/10.1037/a0016127

Wickham, H. (2009). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag. https://doi.org/10.1007/978-0-387-98141-3

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., … Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, *4*(43), 1686.

https://doi.org/10.21105/joss.01686

Wolfgang, C. H., Stannard, L. L., & Jones, I. (2001). Block play performance among preschoolers as a predictor of later school achievement in mathematics. *Journal of Research in Childhood Education*, *15*(2), 173–180. https://doi.org/10.1080/02568540109594958

Woodcock, R. W., Johnson, M. B., & Mather, N. (1989). *Woodcock-Johnson psycho-educational battery—Revised*. DLM Teaching Resources.

Yildiz, B. M., Sasanguie, D., Smedt, B. D., & Reynvoet, B. (2018). Investigating the relationship between two home numeracy measures: A questionnaire and observations during Lego building and book reading. *British Journal of Developmental Psychology*, *36*(2), 354–370. https://doi.org/10.1111/bjdp.12235

Zhang, X., Hu, B. Y., Zou, X., & Ren, L. (2020). Parent–child number application activities predict children's math trajectories from preschool to primary school. *Journal of Educational Psychology*, *112*(8), 1521–1531. https://doi.org/10.1037/edu0000457