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

Kexin Ren[1], Yiqiao Wang[2], Marsha Weinraub[1], Nora S. Newcombe[1], and Elizabeth A. Gunderson[1]
[1] Department of Psychology and Neuroscience, Temple University
[2] Department of Psychology, Harvard University

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 first-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 first grade was negatively associated with boys' (but not girls') math achievement in third 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 multifaceted parent–child interactions.

Keywords: father-child interaction, mother-child interaction, parental praise, parental spatial language, spatial skills

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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; Mutaf 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

Yiqiao Wang https://orcid.org/0000-0003-3214-8045
Marsha Weinraub https://orcid.org/0000-0002-7916-3819
Nora S. Newcombe https://orcid.org/0000-0002-7044-6046
Elizabeth A. Gunderson https://orcid.org/0000-0001-7108-2283

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Correspondence concerning this article should be addressed to Elizabeth A. Gunderson, Department of Psychology and Neuroscience, Temple University, 1701 North 13th Street, Philadelphia, PA 19122, United States. Email: liz.gunderson@temple.edu

(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 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 belief 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 first- and second-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-age 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-age 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 benefited 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 data set used in the present study (the National Institute of Child Health and Human Development [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 (first 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 vs. lab; Bjorklund et al., 2004; Thippana et al., 2020), and have various play structures (e.g., formal vs. 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 and 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 involving 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 prespecified 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 the 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 fourth-grade math achievement (Gunderson et al., 2018). Regarding parental spatial language, Pruden and Levine (2017) also observed that 14- to 46-month-old 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 prekindergarten 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 first-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 first-grade boys and girls in a block-building task.

These mixed results raise two issues that 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 first-grade child engaged in three tasks: (a) an Etch-a-Sketch joint task, (b) a block task, and (c) 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.

Second, we examined whether parental praise and spatial language were associated with children's long-term outcomes including math achievement at third grade and spatial skills at fourth grade, controlling for first-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. Third, we investigated whether parental praise and spatial language showed a multiplicative effect in predicting children's third-grade math achievement and fourth-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). Last, 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 SECCYD. This longitudinal data set 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 data set (e.g., Casey et al., 2018; Lombardi et al., 2017; Thomson et al., 2020). For example, Thomson et al. (2020) examined parental spatial support in first-grade children (same time point as the current study) using data collected at a different site included in the SECCYD data set. 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 first-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 (third grade and fourth 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 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 first grade (N = 107, 56 girls) and correlating newly coded data with standardized scores collected from these same children when they were in third and fourth 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 article, we included only children who interacted with their biological father or stepfather (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 = .35) interacting with their father and 104 children (55 girls; age: M = 7.13 years, SD = .35) interacting with their mother. There were 74 children observed interacting with both parents.

Procedure

Father-Child Interaction

The 15- to 20-min father-child interaction took place in the fall of the child's first-grade year during a semistructured teaching and play situation in the child's home. Father and child completed three tasks, selected to be fun but challenging: (a) an Etch-a-Sketch task where one controlled the vertical knob and the other controlled the horizontal knob to draw a sailboat; (b) a block-building task where the child was asked to build 3D designs using color cubes by copying pictures of the design, with the father's assistance as needed; and (c) 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-min semi-structured teaching and play situation at the university research lab in the spring of the child's first-grade year. Similar to the father-child interaction, mother and child completed three tasks: (a) 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; (b) 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; and (c) 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 .86 at the word level and .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, e.g., "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!"), 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 interrater 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 a 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 three spatial tokens ("triangle," "taller," and "triangle") but only two 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.

[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 $ps \geq .221$).

For interrater 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 min per task, SD = 2.23 min). We excluded interaction data from any task that took less than 2 min.

Children's Mathematics Achievement

Children's mathematics achievement was assessed in the spring of first grade (age: M = 7.13 years, SD = .35) and third grade (age: M = 9.10 years, SD = .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 = .31), using the Block Design subtest of the Wechsler Abbreviated Scale of Intelligence (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 fourth 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 first graders' math achievement from a different site of the SECCYD data set (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 data set, 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 income-to-needs ratio across seven observations (1, 6, 15, 24, 36, and 54 months and first grade) and used it in our analyses. Similarly, we also calculated the average 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 2 years of life.

Additionally, we included ratings of parental stimulation of cognitive development, which had been previously coded in the SECCYD data set based on the same first-grade parent–child 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 nonresponse. 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 nonfather 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 first-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 third-grade math achievement was missing for 15.9% of the sample, and fourth-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 third-grade math achievement and fourth-grade spatial skills separately, using multiple probit regression (Eisner et al., 2019). No predictors were related to missingness of outcome data ($ps \geq .154$). 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 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 on the Interuniversity Consortium for Political and Social Research website (U.S. Department of Health & 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

[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 first grade.

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 nonnormal 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.

Second, we investigated whether and how parental motivational and cognitive support in spatial tasks were related to children's third-grade math achievement and fourth-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 third-grade math achievement and fourth-grade spatial skills on mothers' and fathers' praise and spatial language, controlling for first-grade math achievement, child sex, and child and family covariates. We separated spatial tokens and spatial types in different models to avoid collinearity.

Third, we 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 first-grade math achievement, child sex, and child and family covariates.

Last, 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 online 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 first- and third-grade math achievement and fourth-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,

[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.

Table 1
Generalized Estimating Equation Models With Parental Praise and Spatial Language as Outcomes, Separately by Parent Sex

	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	
Variables	$\chi^2(df)$	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

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 $M = 1.71$, $SE = .15$) than the block task (estimated marginal $M = 1.17$, $SE = .11$, adjusted $p < .001$; Etch-a-Sketch vs. blocks $RR = 1.46$) and the card game (estimated marginal $M = .35$, $SE = .05$, 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 $p < .001$, 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 Type 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 $M = 1.11$, $SE = .09$) and in the block task (estimated marginal $M = 1.19$, $SE = .08$) than in the card game (estimated marginal $M = .44$, $SE = .04$, adjusted ps $< .001$; Etch-a-Sketch vs. card game $RR = 2.56$; blocks vs. card game $RR = 2.74$).

To summarize, parental motivational support differed by task type 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 $M = 15.28$, $SE = .63$) than the block task (estimated marginal $M = 5.19$, $SE = .38$, adjusted $p < .001$; Etch-a-Sketch vs. blocks $RR = 2.94$) and the card game (estimated marginal $M = 4.42$, $SE = .38$, 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 $M = 14.82$, $SE = .57$) than the block task (estimated marginal $M = 3.92$, $SE = .24$, adjusted $p < .001$; Etch-a-Sketch vs. blocks $RR = 3.78$) and the card game (estimated marginal $M = 4.35$, $SE = .25$, adjusted $p < .001$; Etch-a-Sketch vs. card game $RR = 3.41$).[5]

Parental Spatial Types

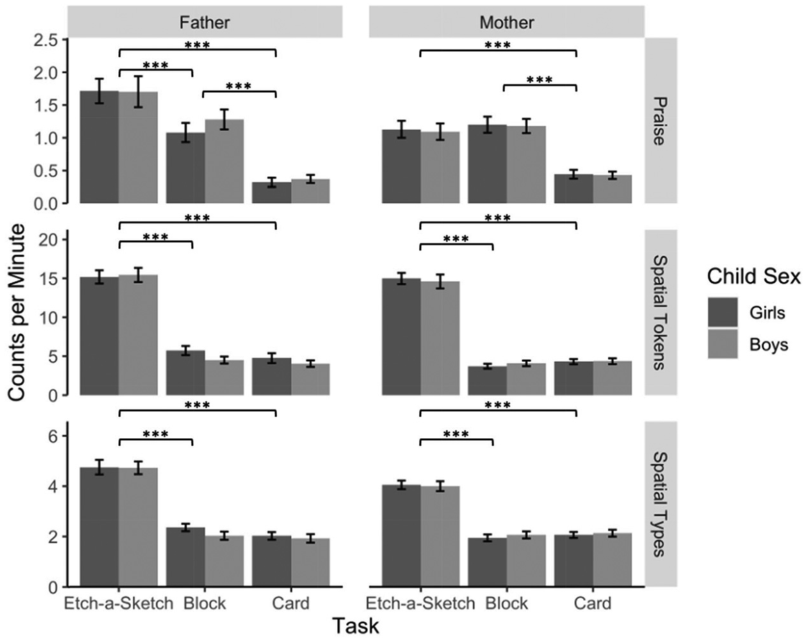
For fathers' use of spatial types, task was significant (see Table 1, Model 5 and Figure 1). However, spatial types did not differ by child sex, and the interaction of Child Sex × Task Type was not significant. Pairwise comparisons between tasks using Holm's Bonferroni corrections showed that fathers had significantly more spatial types in the Etch-a-Sketch task (estimated marginal $M = 4.74$, $SE = .19$) than the block task (estimated marginal $M = 2.21$, $SE = .11$, adjusted $p < .001$; Etch-a-Sketch vs. blocks $RR = 2.14$) and the card game (estimated marginal $M = 1.98$, $SE = .11$, 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 $M = 4.04$, $SE = .13$) than the block task (estimated marginal $M = 2.01$, $SE = .10$, adjusted $p < .001$; Etch-a-Sketch vs. blocks $RR = 2.01$) and the card game (estimated marginal $M = 2.10$, $SE = .09$, adjusted $p < .001$; Etch-a-Sketch vs. card game $RR = 1.92$).

[4] We reran these analyses with process praise only as the dependent variable 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.

[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 (ps $< .001$). Moreover, both parents produced more spatial language in the block task than the card game (ps $< .001$). 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 ($p = .102$).

Figure 1

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



Note. *** $p < .001$.

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 2 to 3 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]

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

Third-Grade Math Achievement

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

Fourth-Grade Spatial Skills

Regressions examining fourth-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 online Supplemental Table S2.

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

[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 dependent variable. 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 ($ps < .001$). 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 ($ps < .001$). The percentage of spatial types out of total speech types shared the same pattern as spatial tokens.

Table 2
Linear Regressions With Children's Math and Spatial Outcomes

	Standardized parameter estimate (*SE*)			
	Third-grade math achievement		Fourth-grade spatial skills	
Variables	Model 1	Model 2	Model 3	Model 4
First-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. $N = 107$. 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, and paternal and maternal cognitive stimulation.
* $p < .003$.

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 ≥ .044). Full model results are shown in online Supplemental Table S3.

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

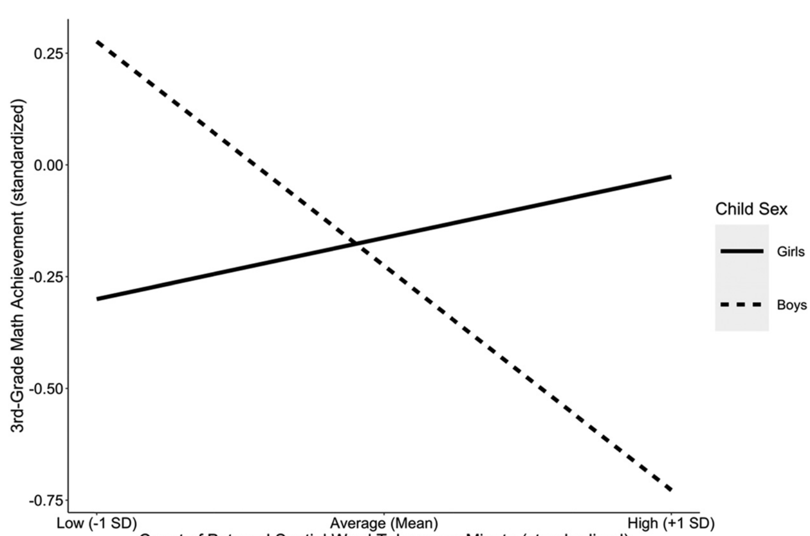
We next examined the interaction between paternal praise and maternal praise, along with the interaction between paternal spatial language and maternal spatial language predicting third-grade math achievement and fourth-grade spatial skills (four total models, shown in online Supplemental Table S4). No interaction terms were significant after Bonferroni corrections (*p*s ≥ .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 spatial tokens had

Figure 2
The Interaction Between Child Sex and Paternal Spatial Language in Relation to Third-Grade Math Achievement



different relations to boys' and girls' math achievement. The simple slope of paternal spatial tokens 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 ($ps \geq .174$). Full model results are shown in online Supplemental Table S5.

Fourth-Grade Spatial Skills

Finally, we examined the interactions of Parent Spatial Tokens × Child Sex and Parent Praise × Child Sex with fourth-grade spatial skills as the outcome. However, no interaction terms were significant ($ps \geq .102$). Full models with covariates are shown in online 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 third grade and spatial skills in fourth 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 third-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 hold opposite goals (in the competitive card game), parents are 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 1-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 vs. 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 subcategories. 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 first-grade children from a different site of the SECCYD data set, 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 first-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 first-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 data set has shown positive associations between quality of teacher-child relationships and children's math and verbal achievement in third 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 first 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 first-grade age may benefit from more advanced spatial talk that targets mental rotation and geometric properties (e.g., talk involving 2D 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 vs. 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 third-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 that found that parents' numeracy talk during Lego building was negatively associated with children's calculation performance (Mutaf 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 first-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 of 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 and played card games with distinct rules, and additionally, children did a 3D cube block-building task with their fathers, whereas children did a 2D 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 third-grade math achievement and fourth-grade spatial skills, children's first-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.

Last, 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.

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