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A sex difference in preschoolers' spatial language use: Parent spatial language input mediates this sex difference

Shannon Pruden and

Florida International University

Susan Levine

University of Chicago

Abstract

Do boys produce more talk about the spatial world (i.e., dimensional adjectives, e.g., *big, little, tall, short*; shape terms, e.g., *circle, square*, and spatial feature/property terms; e.g., *bent, curvy, edge)* than girls? If a sex difference in children's spatial language use is evident, is this difference related to the spatial language parents use when interacting with children? We tracked the development of spatial language production from child age 14–46 months in a diverse sample of 58 parent-child dyads interacting in home settings. Boys produced and heard more 'spatial types' (i.e., unique spatial words), but not more 'other types' than girls. Mediation analysis revealed sex differences in children's spatial talk at 34 to 46 months of age were fully mediated by parent's earlier spatial language use, at child ages 14 to 26 months of age, time points when there was no sex difference in child spatial language use.

Keywords

Spatial language; sex differences; preschool children; parental input; longitudinal study

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Research shows that males are better at mentally transforming objects/shapes and this difference is present in adults (Levine, Foley, Lourenco, Ehrlich & Ratliff, 2016; Linn & Petersen, 1985; Nazareth, Herrera & Pruden, 2013;Voyer, Voyer & Bryden, 1995), children (Frick, Hanson & Newcombe, 2013; Levine, Huttenlocher, Taylor & Langrock, 1999; Levine, Vasilyeva, Lourenco, Newcombe & Huttenlocher, 2005; Neubauer, Bergner & Schatz, 2010), and even infants (Moore & Johnson, 2008; Quinn & Liben, 2008). Surprisingly, there has been no investigation of whether there is a male advantage in spatial language use or exposure in childhood even though there is evidence that spatial language is related to and supports spatial thinking (Dessalegn & Landau, 2013; Gentner, Özyürek, Gürcanli & Goldin-Meadow, 2013; Hermer-Vasquez, Moffet & Munkholm, 2001; Pruden, Levine & Huttenlocher, 2011; Pyers, Shusterman, Senghas, Spelke & Emmorey, 2010; Shusterman, Lee & Spelke, 2011; Verdine, Lucca, Golinkoff, Hirsh-Pasek, & Newcombe, 2016).

Address correspondence to: Shannon Pruden, Florida International University - Psychology, 11200 SW 8th St. DM 206 Miami Florida 33199, Phone: 305-348-2784; Fax: 305-348-3879; sdick@fiu.edu.

Data available by request, please contact first author, S. Pruden at sdick@fiu.edu.

The current investigation asks whether there is a sex difference in preschoolers' use of spatial language, in favor of boys, and whether this is related to a gender-related difference in parent spatial language use. Such a finding would open the possibility that a gender difference in spatial language use contributes to the well-documented sex differences on tasks such as mental rotation and would open a new route to improving children's spatial thinking skills, and to narrowing sex differences in spatial thinking (Costales, Abad, Odean & Pruden, 2015; Levine, Lourenco, Ratliff & Ehrlich, 2016).

The present study

Using a longitudinal design, we tracked the spatial language production (from 14- to 46-months) in a diverse sample of parent-child dyads. All child and parent speech during nine 90-minute observations, during which parents were told to do what they normally do, was transcribed and coded for spatial language. We focused on a particular set of spatial words – words describing the size, shape, and spatial properties of objects, animates, and spaces. We focused on these spatial words rather than those describing "where" the object is located in space (e.g., *far, over, between)* because use of the "where" words was highly correlated (i.e. collinear) with overall language use ("talkativeness"), whereas this was not the case for "what" spatial terms (Pruden et al., 2011). Thus, our focus on the "what" spatial words was driven by the practical difficulty of separating effects involving use of "where" spatial words from overall language use, rather than by the hypothesis that "what" spatial words are more important to spatial thinking than "where" spatial words (see Landau & Jackendoff, 1993 and Verdine, Lucca, Golinkoff, Hirsh-Pasek & Newcombe, 2016 for more about what/where words).

Although parent spatial language use may be linked to the differential engagement of boys versus girls in spatial activities such as block play, the present study does not focus on contexts of spatial language use. Rather, we take the first step of examining whether there *is* a sex difference in spatial language use and exposure, and consider the issue of context in our discussion.

The current investigation asks three questions: (1) Are there sex differences in children's spatial language use? (2) Do parents use more spatial language with boys than girls? (3) Does parent spatial language use mediate the relation between child sex and child spatial language use?

Method

Participants

Our sample included 58 typically-developing children (30 males; 28 females) and their primary caregivers (52 mothers; 1 father; 5 dual caregivers) from homes in the greater Chicago area. Primary caregiver-child dyads were part of a larger, longitudinal study of children's language development in which 64 families had been recruited for a longitudinal project examining the relation between parent input and child language development. All children were monolingual English-speakers. Of the 30 male children, 20 were first born and 10 were later born; of the 28 female children, 13 were first born and 15 were later born. Six primary caregiver-child dyads were not included in the final sample because they had participated in fewer than 8 of the 9 observation sessions between 14 to 46 months, resulting in less opportunity for the observation of their spatial language.

Families were recruited via an advertisement in a parenting magazine or by a mailing to families living in the Chicago area. Interested families completed a screening interview in which they were asked about their demographic information (i.e., family income, primary caregivers' education, primary caregivers' occupation, race/ethnicity, and child's sex). Those families included in our final sample represented the demographics of the greater Chicago area as measured by family income and race/ethnicity. The demographic information of our final sample, including family income and child's race/ethnicity, is shown in Table 1.

Primary caregivers varied in their educational backgrounds, with 8 primary caregivers reporting they had completed high school but not beyond, 11 primary caregivers reporting they had taken some college courses or had attended a post-high school trade school, 21 primary caregivers reporting a college degree (i.e., Bachelors), and 18 primary caregivers reporting a graduate or professional degree (i.e., Masters, Doctorate, etc.). The average income for our sample fell within the $50,000 and $74,999 range. Socioeconomic status (SES) was computed by creating a composite score of primary caregiver's education level and family income, as principle components analysis on this sample have previously shown that these two components weighted equally account for 72% of the variance (Rowe & Goldin-Meadow, 2009). SES factor scores were used as a covariate in our mediation analyses to ensure that effects were not explained by SES.

Procedure

Parent-child dyads were visited every four months between child age 14 months and 46 months of age. Dyads were videotaped for an average of 90 minutes during each visit. Primary caregivers were instructed to do what they ordinarily would do during the visits. No toys or specific objects were given to the dyads. A typical visit included activities such as toy play, book reading, and meal or snack time, but no instructions were given about what activities to engage in. In the event that the primary caregiver was engaged in different activities than their child (e.g., child was playing with toys while caregiver was in the kitchen preparing a snack), the research assistant continued to videotape the child.

Coding, Reliability, and Dependent Variable

Children's and their primary caregiver's speech were transcribed for all 9 visits (i.e., 14-, 18-, 22-, 26-, 30-, 34-, 38-, 42-, and 46-months). Transcriptions were conducted by trained research assistants using the established procedures outlined in Huttenlocher et al. (2007). To ensure reliability, a random 20% of transcripts were selected and a second trained research assistant independently coded 10% of children's utterances from these transcripts. Inter-rater reliability between the first and second research assistant's transcription of utterances was $r > .95$.

For each child and parent we calculated the cumulative number of "what" spatial types (i.e., unique "what" spatial words) and tokens (i.e., all "what" spatial words) used during nine observation sessions between 14 and 46 months. We also assessed the use of other words (i.e., 'other types' and 'other tokens') for each parent and child by calculating cumulative 'other types' and 'other tokens.'

The following three categories of spatial words were coded and targeted for further analysis. Using the system for analyzing children's language about space (Cannon, Levine & Huttenlocher, 2007), we coded:

> *Shape terms*: Words that are the mathematical names of two- and three-dimensional objects and spaces. For example, words such as *circle, triangle, octagon*, and the word, *shape*, were included.
>
> *Dimension terms*: Words that describe the size of objects, people and spaces. Words such as *big, little, tall, tiny, small*, tall, short and *long* were included.
>
> *Spatial features terms*: Words that describe the features and properties of two- and three-dimensional objects, people, and spaces. Words included in this category included, *bent, curvy, edge, side, line*, and *corner*.

Our coding system identified approximately 100 unique dimensional adjectives, shape terms and spatial feature/property terms. The first author identified and coded targeted spatial words; when there were questions about the word's usage, the first author and second author met to determine whether its usage was spatial and the category to which it belonged.

Targeted words that were not used in a spatial manner were excluded from our final word counts. For example, homonyms with meanings that may not have been spatial (e.g., "Are you my *big* boy?" and "You are a *little* angel."), metaphorical uses (e.g., "That took a *long* time" and "You have a *big* heart"), spatial words used in names (e.g., "*Big* Bird" and "*Little* Drummer Boy"), and other spatially ambiguous usages (e.g., "It will only be a *short* walk" might refer to time) were not considered spatial uses.

Portions of the current data were previously used to examine the relationship between parent spatial language and child spatial cognition and spatial language use (Pruden et al., 2011). However, this previous study did not explore sex differences in children's spatial language use or their parent spatial language input, the focus of the current study.

Results

For each child and primary caregiver, the number of 'spatial types' (i.e., unique words produced; e.g., *big* and *little* are two unique types of spatial words) and the number of 'spatial tokens' (i.e., actual number of spatial words produced, e.g., big used 5 times would be counted as 5 tokens) was calculated across the 9 time points to yield a cumulative 'spatial types' and 'spatial tokens' scores. This cumulative total included the production of 'spatial types' and 'spatial tokens' across all three "what" spatial language categories coded (i.e., *dimensions, shapes*, and *features)*. We summed across all three "what" spatial language categories as analysis revealed no sex by spatial language category interaction. One child (female) was identified as an outlier (more than 2 *SD* above the group mean) using the standardized z-scores of 'spatial types.' This child's data were not included in any further analyses as this child was considered an outlier in their spatial language production. When data from this outlier were included in all further analyses, the sex difference between boys' and girls' production of 'spatial types' was not significant (p=.07). This child's parent 'spatial types' and 'spatial tokens' *were within* 2 SD's from the mean.

We also calculated children's and parents' cumulative 'other types' and 'other tokens' by 46 months of age. This was calculated by tallying all word types and all word tokens the child and parent had produced and subtracting the number of 'spatial types' or 'spatial tokens' to yield a number corresponding to 'other types' and 'other tokens' for each child and parent. These variables were used as a covariate in the mediation analyses to test whether effects are related to differences in spatial language or to overall language use. However, in cases where our spatial language variable was collinear with our overall language variable, as was found with 'spatial types' and 'other types,' we ran a separate analysis with 'other types' to determine whether our effects were unique to 'spatial types' and not a product of overall language use.

Observation sessions averaged 90 minutes (~810 minutes total) at each time point but varied somewhat across dyads (M= 787.65, SD=33.26; *Range*=679.33–812.40 minutes). Because of this, we controlled for the time over which children were observed in our analyses.

Are there sex differences in children's spatial language use?

The first aim of this study was to examine whether there are sex differences in children's use of spatial and non-spatial language, with the prediction that boys would produce more spatial talk than girls, but would not significantly differ in their amounts of non-spatial talk from 14 to 46 months of age. For all analyses we used cumulative types and tokens of "across all 9 time points and *all* "what" spatial words, as no analysis revealed an interaction with category (i.e., dimensional adjectives, shapes, and spatial features) of "what" spatial words.

The mean cumulative 'spatial types' and 'spatial tokens,' and 'other types' and 'other tokens,' across the nine sessions as well as standard deviations and ranges, are reported in Table 2. Descriptive statistics for children language use revealed considerable variability in 'spatial types' and 'spatial tokens,' as well as differences by child sex. Not surprisingly, some children used relatively few spatial types and spatial tokens across the nine visits that occurred between 14 and 46 months of age whereas others used substantially more. Moreover, the spatial language children produced predicted their spatial skills on nonverbal tasks (Pruden et al., 2011).

Child Types—A MANOVA with child sex as the independent variable and child word types ('spatial types'; 'other types') as the dependent variable was significant, $F(2,54)=3.55$, p=.04, η_p^2 =.17. Planned univariate ANOVAs revealed that boys produced significantly more 'spatial types' than girls by 46 months of age, $F(1,55)=4.91$, p=.03, η_p^2 =.08 (Figure 1a, bottom right), but did not differ from girls in their production of 'other types', $F(1,55)=0.89$, p=.77, η_p^2=.002. This significant sex difference in children's production of 'spatial types' held when controlling for family SES [$F(1,54)=4.076$, p=.048, η_p^2 =.07], time over which language samples were obtained [$F(1,54)=3.95$, p=.05, η_p^2 =.068], birth order of the child [$F(1,54)=4.007$, p=.05, η_p^2 =.07; included because some studies report birth order effects on language; Hoff-Ginsberg, 1998], and primary caregiver gender [$F(1,54)=4.68$, $p=.035$, $\eta_p^2=.08$]. Further, even after controlling for family SES [$F(1,54)=.001$, $p=.988$, $\eta_p^2 < .001$], time during which language samples were obtained [$F(1,54)=.001$, $p=.992$, $\eta_p^2 < .001$], birth order of the child [$F(1,54)=.002$, $p=.965$, $\eta_p^2 < .001$], and primary caregiver gender [$F(1,54)=.002$ $p=.965$, $\eta_p^2 < .001$], there were still no significant differences in boys and girls in their production of 'other types.' These results suggest that the difference in spatial language production does not just reflect greater talkativeness (i.e., use of other types) of boys than girls, and that this sex difference remained even when controlling for a variety of potential covariates.

Child Tokens—A MANOVA with child sex as the independent variable and child word tokens ('spatial tokens'; 'other tokens') as the dependent variable was not significant, $F(2,54)=3.016$, $p=.06$, $\eta_p^2=.10$. Planned univariate ANOVAs showed that boys produced marginally more, but not significantly more, 'spatial tokens' than girls $F(1,55)=3.258$, p=.08, $\eta_p^2=.056$, but girls and boys did not significantly differ in their production of 'other tokens,' $F(1,55)=.053$, $p=.82$, $\eta_p^2=.001$, with girls producing numerically more overall words. When controlling for family SES [$F(1,54)=2.50$, $p=.12$, $\eta_p^2=.044$], time over which language samples were obtained [$F(1,54)=2.668$ $p=.108$, $\eta_p^2=.047$], birth order of the child [$F(1,54)=2.438$, $p=.124$, $\eta_p^2=.043$], and primary caregiver gender [$F(1,54)=2.973$, $p=.09$, $\eta_p^2=.052$] the male-female difference in 'spatial tokens' remained marginally significant. Further, even after controlling for family SES [$F(1,54)=.301$, $p=.585$, $\eta_p^2=.006$], time during which language samples were obtained [$F(1,54)=.262$, $p=.611$, $\eta_p^2=.005$], birth order of the child [$F(1,54)=.264$, $p=.610$, $\eta_p^2=.005$], and primary caregiver gender [$F(1,54)=.002$ $p=.966$, $\eta_p^2 < .001$], there were still no significant differences in boys and girls in their production of 'other tokens.'

Are there sex differences in parent's spatial language use?

The second aim of the study was to examine whether parents used more 'spatial types' (and 'other types') and/or more 'spatial tokens' with boys than with girls. For these analyses we used cumulative types and tokens across all 9 time points, again summing over the three categories of "what" spatial words as a category, as the three sub-categories of "what" spatial words did not show any significant interactions by sex. In Table 3 we report the mean cumulative 'spatial types' and 'spatial tokens,' and 'other types' and 'other tokens' parents of boys and girls produced, across the nine sessions, as well as standard deviations and ranges.

Parent Types—A MANOVA with child sex as the independent variable and parent word types ('spatial types'; 'other types') as the dependent variable was significant, $F(2,54)=3.43$, $p=.04$, $\eta_p^2=.11$. Planned univariate ANOVAs showed that parents produced significantly more 'spatial types' when interacting with boys than girls, $F(1,55)=6.83$, $p=.01$, $\eta_p^2=.11$ (Figure 1a, bottom left). The significant sex difference in parent production of 'spatial types' held when controlling for family SES [$F(1,54)=6.33$, $p=.015$, $\eta_p^2=.11$], time during which language samples were obtained [$F(1,54)=5.788$, $p=.02$, $\eta_p^2=.10$], birth order of the child [$F(1,54)=5.789$, $p=.02$, $\eta_p^2=.10$], and primary caregiver gender [$F(1,54)=5.755$, $p=.02$, $\eta_p^2=.10$]. Parents also produced marginally more 'other types' when interacting with boys than girls $F(1,55)=3.408$, $p=.07$, $\eta_p^2=.058$. However, when controlling for family SES [$F(1,54)=2.63$, $p=.11$, $\eta_p^2=.046$], time during which language samples were obtained [$F(1,54)=2.56$, $p=.12$, $\eta_p^2=.045$], birth order of the child [$F(1,54)=2.63$, $p=.11$, $\eta_p^2=.046$], and primary caregiver gender [$F(1,54)=1.84$, $p=.18$, $\eta_p^2=.033$], this marginal difference sex difference reduced to non-significance.

Parent Tokens—A MANOVA with child sex as the independent variable and parent word tokens ('spatial tokens'; 'other tokens') as the dependent variable also was significant, $F(2,54)=6.05$, $p=.004$, $\eta_p^2=.18$. Planned univariate ANOVAs revealed that parents produced significantly more 'spatial tokens' with boys than girls, $F(1,55)=10.79$, $p=.002$, $\eta_p^2=.16$. The significant sex difference in parent production of 'spatial tokens' held when controlling for family SES [$F(1,54)=10.183$, $p=.002$, $\eta_p^2=.159$], time during which language samples were obtained [$F(1,54)=9.508$, $p=.003$, $\eta_p^2=.15$], birth order of the child [$F(1,54)=9.457$, $p=.003$, $\eta_p^2=.149$], and primary caregiver gender [$F(1,54)=9.65$, $p=.003$, $\eta_p^2=.152$]. Parents also significantly differed in their production of 'other tokens' to boys versus girls, $F(1,55)=11.28$, $p=.001$, $\eta_p^2=.17$, with parents using significantly more word tokens when interacting with boys than with girls. This significant difference held when controlling for family SES [$F(1,54)=11.003$, $p=.002$, $\eta_p^2=.169$], time during which language samples were obtained [$F(1,54)=10.036$, $p=.003$, $\eta_p^2=.157$], birth order of the child [$F(1,54)=9.538$, $p=.003$, $\eta_p^2=.150$], and primary caregiver gender [$F(1,54)=8.663$, $p=.005$, $\eta_p^2=.138$]. Given that the sex difference in parent production of language is not unique to 'spatial tokens,' but also includes 'other tokens,' we focused all further analyses on parent 'spatial types.'

Does parent input mediate the sex difference in children's spatial talk?

To review, we found that boys produced a greater variety of spatial words than girls (spatial types) but not more overall spatial words (spatial tokens), and that the same was true of parents of boys versus girls. Further, for both children and parents, we did not find that the variety of other words (other word types) differed by child gender. The third and final aim of the present study was to evaluate whether parent spatial types mediated the relation between child sex and child spatial types (note that we cannot carry out this analysis on spatial tokens since a significant difference in the number of 'spatial tokens' boys and girls produced is a necessary finding to carrying out a mediation analysis; Baron & Kenny, 1986).

To meet the prerequisites of a mediation analysis, we first ran regressions to confirm the existence of the following relations: (a) a significant relation between the predictor variable (child sex) and outcome variable (child 'spatial types'); (b) a significant relation between the predictor variable (child sex) and mediating variable (parent 'spatial types'), and; (c) a significant relation between the mediating variable (parent 'spatial types') and the outcome variable (child 'spatial types'). Once these significant relations were established, the mediation analysis can proceed through linear regression with parent 'spatial types' as a potential mediator between child sex and child 'spatial types.' For these analyses we used cumulative types across all 9 time points. Regression analysis showed child sex significantly predicted child 'spatial types' ($\beta = 0.55$, $t=2.22$, $p=.03$; Figure 1b illustrates path *c*), and child sex significantly predicted parent 'spatial types' ($\beta= 0.64$, $t=2.61$, $p=.01$; Figure 1c illustrates path *a*). Finally, parent 'spatial types' predicted child 'spatial types' ($\beta= 0.70$, *t*=7.19, *p*<.001; Figure 1c illustrates path *b*). Thus, the prerequisite relations between all three variables of interest were met for a mediation analysis to be conducted.

When parent 'spatial types' were included as a potential mediator, the path coefficient (c') was significantly reduced and no longer significant (β=0.10 *t*=0.51, *p*=.61; Figure 1c illustrates path c'). This suggests that parent 'spatial types' fully mediates the sex difference in child 'spatial types' production. A bias-corrected bootstrapping procedure (1000 iterations; Preacher & Hayes, 2004) provided a 95% confidence interval of −0.81 to −0.08. This bias corrected confidence interval did not contain zero, suggesting that the reduction in the direct relation between child sex and child 'spatial types' was significant. These results suggest a full mediation of the relation between child sex and child 'spatial types' with parent 'spatial types' accounting for the sex difference in child 'spatial types.' This model accounted for over 51% of the variance (based on adjusted R^2) in children's production of 'spatial types.'

Our effects held, with reported path coefficients remaining the same in terms of their significance, after controlling for child 'other types,' family SES, length of language transcripts, birth order of the child, and primary caregiver gender in follow-up mediation analyses with covariates entered (see Table 4 for covariate results and adjusted R^2 of each model; adjusted R^2 range with covariates = 0.5048–0.6303). A potential criticism is that parent 'other types' could explain the mediation. However, not surprisingly, parent 'other types' are highly correlated with parent 'spatial types' ($r = 0.81$, $p < .001$, two-tailed). This multicollinearity precludes including both in the same mediation model (Iacobucci, 2008; Jaccard & Turrisi, 2003). We did, however, run the same mediation model with parent 'other types' as the mediator instead of parent 'spatial types'. The expectation would be that if parent language in general is responsible for the sex difference in child spatial types, then parent 'other types' would mediate the relation in the same way as parent 'spatial types'. The relation between the predictor variable (child sex) and the mediating variable (parent 'other types') was not significant, β =0.48, *t*=1.85, *p*=.07 (path *a*), however the relation between the mediating variable (parent 'other types') and the outcome variable (child 'spatial types') was significant, β =0.50, *t*=4.49, *p*<.001 (path *b*), and, as reported in prior analyses above, the relation between the predictor variable (child sex) and outcome variable (child 'spatial types') was also significant, β =0.55, *t*=2.22, *p*=.03 (path *c*). While there was statistically no path for mediation given the lack of a significant *ab* path (though see recent methodological papers, Hayes 2009, 2013), when parent 'other types' were included as a potential mediator, the path coefficient (c') was significantly reduced and no longer significant (β=0.31 *t*=1.41, *p*=.16). This suggests that parent 'other types' may also be a potential mediator of the reported sex difference in child 'spatial types' production. A bias-corrected bootstrapping procedure (1000 iterations; Preacher & Hayes, 2004) provided a 95% confidence interval of 0.0034 to 0.5164. This bias corrected confidence interval did not contain zero, suggesting that the reduction in the direct relation between child sex and child 'spatial types' was significant. This model accounted for 31% of the variance (based on adjusted R^2) in children's production of 'spatial types.' These findings leave open the question of whether parent use of spatial language is a specific predictor of child spatial language or whether these findings might simply be explained by parent overall language use with their children. We return to this issue below when we examine whether parent ‘other types’ mediates sex difference in child ‘spatial types’ using lagged data.

We next tested whether children could be driving this effect via testing the reverse causal mediation model whereby child ‘spatial types’ served as the mediator between our predictor variable (child sex) and our outcome variable, parent ‘spatial types.’ When child ‘spatial types’ were included as a potential mediator between child sex and parent ‘spatial types,’ the path coefficient (c') was significantly reduced and no longer significant (β=0.26 t=1.41, p=.1635). This suggests that child ‘spatial types’ fully mediated the sex difference in parent ‘spatial types’ production. This model accounted for 52.87% of the variance (based on adjusted R^2) in parent’s production of ‘spatial types,’ suggesting there may be effects of children’s production of spatial types on parents’ production of spatial types, leaving open the possibility that sex differences in spatial language production may be driven not by parents but by children, or be bidirectional. To further explore the directionality of the sex difference, we used a lagged analysis of our longitudinal data with parents and children.

Lagged analysis of longitudinal data

To further probe whether parents are driving the sex difference in children’s spatial language production, we ran an additional mediation model utilizing parents’ ‘spatial types’ produced during the first four visit time points (14 months – 26 months; i.e., early time points) and children’s ‘spatial types’ produced during the last four visit time points (34 months – 46 months; later time points). This model is less likely to suffer from reverse causal effects (child to parent), and thus allows us to make a stronger case that it is parent spatial language input that may be driving the sex difference in children’s spatial language production (and not children’s production explaining parents’ production). In addition, we continued to explore whether parent ‘other types’ might be an alternative plausible mediator of the sex difference in children’s ‘spatial types.’

Like the previous result with 9 time points for both children and parents, we replicated our findings utilizing four different time points for children and parents. Parents produced, on average, 11.57 (*SD*=4.60; *Range*=3–21) ‘spatial types’ to boys, and 8.07 (*SD*=4.36; *Range*=0–18) ‘spatial types’ to girls, when the children were between 14 and 26 months (early time points). A MANOVA with child sex as the independent variable and parent word types (‘spatial types’; ‘other types’) during the early time points (14 – 26 months) as the dependent variable was significant, $F(2,54)=4.47$, $p=.02$, $\eta_p^2=.14$. Planned univariate ANOVAs showed that parents produced significantly more ‘spatial types’ when interacting with a male child during the early time points than when interacting with a female child during that same time frame, $F(1,55)=8.61$, $p=.005$, $\eta_p^2=.14$ (Figure 2a, bottom left). Moreover, parents did not significantly differ in their production of ‘other types’ to boys versus girls during the early time points, $F(1,55)=2.44$, $p=.124$, $\eta_p^2=.04$, suggesting again that parents did not generally provide more diverse vocabulary to boys than girls during the first two years of life. Looking at children’s production of ‘spatial types’ between 34 and 46 months of age (i.e., later time points), boys produced, on average, 10.23 (*SD*=5.16; *Range*=2–21) ‘spatial types’ and girls produced, on average, 7.74 (*SD*=3.98; *Range*=1–17) ‘spatial types’. A MANOVA with child sex as the independent variable and child word types ('spatial types'; 'other types') during the later time points (34 – 46 months) as the dependent variable did not reach significance, $F(2,54)=2.09$, $p=.13$, $\eta_p^2=.07$.

Planned univariate ANOVAs showed that boys indeed produced more 'spatial types' than girls at the later time points (34- to 46-months), $F(1,55)=4.11$, $p=.048$, $\eta_p^2=.07$ (Figure 2a, bottom right), but did not significantly differ in their production of 'other types' during this time frame, $F(1,55)=0.24$, $p=.63$, $\eta_p^2=.004$. These results suggest that even when looking at how parent spatial types at earlier time points predict child spatial types at later time points, boys produced significantly more 'spatial types' than girls, but not more 'other types' than girls.

We also asked whether boys and girls differ in their 'spatial types' and 'other types' between the ages of 14 and 26 months, our earliest four time points. Boys produced, on average, 2.30 (*SD*=2.18; *Range* = 0–8) 'spatial types' and girls produced, on average, 1.70 (*SD*=1.98; *Range* = 0–7) 'spatial types' during the early time points (i.e., 14- to 26-months). At these early time points, boys produced, on average, 215.20 (*SD*=133.91; *Range* = 6–493) 'other types' and girls produced, on average, 232.07 (*SD*=122.20; *Range* = 41–558) 'other types'. A MANOVA with child sex as the independent variable and child word types ('spatial types'; 'other types') during these early time points (14–26 months) as the dependent variable was not significant, $F(2,54)=2.43$, $p=.10$, $\eta_p^2=.08$. Planned univariate ANOVAs revealed no significant sex difference in either child 'spatial types,' $F(1,55)=1.16$, $p=.29$, $\eta_p^2=.02$, or child 'other types,' $F(1,55)=0.25$, $p=.62$, $\eta_p^2=.004$ at these early time points, suggesting that children's own initial sex difference in spatial language use is not a plausible explanation for either their later sex difference in spatial word types or for parents' greater use of spatial word types with boys than girls at the early (or later) time points. This lack of an early sex difference in children's spatial types also precluded carrying out a lagged analysis examining whether an early sex difference in children's spatial types predicted a later parent sex difference in spatial types.

We next explored whether parents' greater use of spatial types with boys versus girls at the early time points provides a plausible explanation for boys' greater use of spatial types at the later time points. Regression analysis showed child sex significantly predicted child 'spatial types' produced at the four later time points ($\beta = 0.52$, $t=2.03$, $p=.0476$; Figure 2b illustrates path *c*), and child sex significantly predicted parent 'spatial types' using only those parent spatial types produced at the four early time points ($\beta= 0.73$, $t=2.93$, $p=.0049$; Figure 2c illustrates path *a*). Finally, parent 'spatial types' produced at the early time points predicted child 'spatial types' produced at the later time points ($\beta= 0.39$, $t=3.02$, $p=.0039$; Figure 2c illustrates path *b*). When parent 'spatial types' produced between 14 and 26 months were included as a mediator, the path coefficient (c') was significantly reduced and no longer significant ($\beta=0.23$ $t=0.9084$, $p=.37$; Figure 2c illustrates path c'), suggesting that parent 'spatial types' input fully mediates the sex difference in child 'spatial types' production. The bias-corrected bootstrapping procedure (Preacher & Hayes, 2004) gave a 95% confidence interval that did not contain zero (−0.84 to −0.03), suggesting that the reduction in the direct relation between child sex and child 'spatial types' was significant. This model accounted for 17% of the variance in child 'spatial types.'

Like our analysis above with all time points, we wanted to ensure that our finding here was not simply that parent 'other types' between 14 and 26 months of age was explaining the sex differences in children's 'spatial types' between 34 and 46 months. As with our previous analysis, we, not surprisingly, found that parent 'other types' between 14 and 26 months are highly correlated with parent 'spatial types' ($r = 0.72$, $p < .001$, two-tailed), again revealing multicollinearity as an issue in using both variables in the same model. Thus, we again ran a separate mediation model with parent 'other types' between 14 and 26 months of age as the mediator instead of parent 'spatial types' between 14 and 26 months of age. Contrary to the model that utilized parent talk and child talk at *all time points*, we did not find evidence that parent 'other types' at the early time points mediates the relation between child sex and child 'spatial types' at the later time points. Like the mediation model reported above with all time points, there was no significant relation between the predictor variable (child sex) and the mediating variable (parent 'other types' between 14 and 26 months), $\beta = 0.41$, t=1.56, p=.12. Similar to the model with all time points, there was a significant relation between the mediating variable (parent 'other types') and the outcome variable (child 'spatial types'), β =0.39, t=3.17, p=.003 (path *b*), and the relation between the predictor variable (child sex) and outcome variable (child 'spatial types') was also significant, β =0.52, t=2.06, p=.048 (path *c*). While there was statistically no path for mediation given the lack of a significant *ab* path (though see recent methodological papers, Hayes 2009, 2013), when parent 'other types' were included as a potential mediator, the path coefficient (c') was significantly reduced and no longer significant (β=0.36 t=1.49, p=.14). Unlike our previous analysis with the all time points, the bias-corrected bootstrapping procedure (1000 iterations; Preacher & Hayes, 2004) provided a 95% confidence interval of −0.0089 to 0.4030 and thus, did contain zero, suggesting that the reduction in the direct relation between child sex and child 'spatial types' was *not significant*. This model accounted for less than 19% of the variance (based on adjusted R^2) in children's production of 'spatial types.' This mediation model, in conjunction with the model testing parent 'spatial types' as a possible mediator, point to the unique role that parent 'spatial types' plays in explaining the sex differences in children's 'spatial types.' These findings with only the first 4 time points for parent 'spatial types' and the last 4 time points for child 'spatial types' suggest that parent spatial language input may be *driving* the sex difference in children's spatial language production (and not children's production of spatial types explaining parents' production of these word types).

Discussion

This study addressed two questions: (1) is there a sex difference in child spatial language production, with boys producing more spatial talk than girls, and; (2) do parents of boys and girls differ in their spatial language use with their children, potentially explaining this sex difference. With regard to our first question, we found a sex difference in the production of spatial language during preschool years, which was significant during naturalistic interactions occurring between 34- and 46-months, but not earlier. Boys produced more unique "what" spatial words (i.e., dimensional adjectives, shape words, and spatial feature words). This sex difference in spatial language production is a potential contributor to documented sex differences in spatial skills, including mental rotation, as research finds that spatial language use is related to children's performance on nonverbal spatial tasks (Gentner & Loewenstein, 2002; Gentner et al., 2013; Pruden et al., 2011).

Our second question, whether parent spatial language use contributes to the sex difference in children's spatial language use was motivated by research finding that the most important factors predicting children's later language growth is frequency and type of language experiences (i.e., amount and type of language children hear; Hart & Risley, 1995; Hoff & Naigles, 2002; Huttenlocher et al., 1991). Variance estimates suggest early language input accounts for between 12 and 64 percent of unique variance in children's later language skills (Walker et al., 1994). Research has shown that parent use of specific words predicts children's use of those words. Parent use of number words with 14- to 30-month-olds predicts children's number talk and their later understanding of cardinal meaning of number words (Levine et al., 2010; Gunderson & Levine, 2011). Utilizing a longitudinal design, we examined whether parent use of spatial language mediates the sex difference found in children's spatial word use. Mediation analyses confirmed that parents' 'spatial types' to children fully mediated the sex difference in children's production of unique spatial words, controlling for a variety of variables. This mediation produced similar results when parent and child sessions were contemporaneous (9 time points between child ages 14- and 46-months) and when they were distinct (parent spatial types produced from 14- to 26-months and child spatial types between 34- and 46-months). Results suggest parent spatial language input is an important predictor of children's spatial productive vocabularies. Although multicollinearity of spatial language input with other language input precluded our entering both types of parent language input into the same analysis, using separate analyses we found that parent 'spatial types' mediated the relation between child sex and child 'spatial types' whereas parent 'other types' did not.

One finding was surprising given previous literature examining spatial language development (e.g. Pruden et al., 2011) where quantity of parent spatial tokens significantly predicted children's quantity of spatial tokens and their later spatial skills. Although we found results for spatial tokens were in the same direction as results for spatial types, we did not find a significant sex difference in children's production of spatial tokens (sheer number of spatial words produced). Rather, we found that the sex differences for parents and children were significant for the variety of spatial words produced. The lack of token effects may be a product of our small sample size, and our effect sizes for spatial tokens suggest this may be the case.

Although the sex difference in the number of unique spatial words children hear and produce is small, it is potentially meaningful. In a prior study, based on the same database, we found that children's own use of spatial language in the first four years of life predicted their spatial skills at 4.5-years-old (Pruden et al., 2011). Those children who talked more about the spatial world had better spatial skills – skills linked to achievement in Science, Technology, Engineering and Mathematics (STEM) disciplines (e.g., mental rotation is linked to success in STEM college courses; Wai, Lubinski, Benbow & Steiger, 2010; mental rotation is linked to number line representations and ability to solve missing term problems in elementary-school children; Gunderson, Ramirez, Beilock, & Levine, 2013; Cheng & Mix, 2014). Thus, our findings have potential practical implications for efforts to enhance spatial thinking, which has been shown to be a significant predictor of STEM achievement (Wai, Lubinski & Benbow, 2009).

What contributes to the sex difference we uncovered in parent and child spatial language use? First, it is possible that child spatial language use drives parent spatial language use, rather than the reverse. This seems unlikely given that parents provided more spatial language to boys at early time points when there was not a significant sex difference in child spatial language, and this early parent difference predicted the later sex difference in child spatial language whereas the reverse was not true – that is, we did not find that an early sex difference in child spatial language predicted a later sex difference in parent spatial language. However, our correlational findings cannot rule out the possibility of reverse causation or that there is a bidirectional relation between parent and child spatial language use. Second, it is possible that parents use more spatial language with boys because boys engage more in spatial activities (e.g., blocks, Legos; Cherney & Voyer, 2010; Kersch, Casey & Young, 2008), and/or find construction activities more attractive (Caldera, Huston & O'Brien, 1985; Campenni, 1999). There is evidence that spatial language occurs more commonly in the context of spatial activities than in the context of non-spatial activities and evidence that boys play more with certain spatial toys than girls, including blocks and Legos (Caldera et al., 1985; Ferrarra, Hirsh-Pasek, Newcombe, Golinkoff & Lam, 2011; Kersh, Casey & Young, 2008; Saracho, 1994) and Legos (Caldera et al., 1985; Campenni, 1999). Third, it is possible that parents hold stereotypes about boys being better at spatial thinking than girls, and as a consequence, may provide boys with more opportunities for spatial play, which could increase boys' exposure to spatial language. Finally, it is possible that parents support the spatial play of girls and boys differently. Parents may work harder to support the success of boys than girls in spatial activities, perhaps by providing more spatial language to them. There is evidence this may be the case in contexts of parent-child puzzle play (Levine, Ratliff, Huttenlocher & Cannon, 2012; Ping, Bradley, Rayman-Kinney, & Levine, 2013) and block play (Petersen & Levine, 2015).

These open questions can be addressed by *experimentally manipulating* adults' spatial language use with children and examining how this affects children's spatial language production and thinking. It is also important to compare spatial language provided to boys and girls by mothers and fathers in a study that includes more fathers interacting with their children. Future work will also need to determine whether the findings we report for "what" spatial words generalize to all types of spatial words. Here we selectively examined spatial words that encode spatial features of objects (shape terms, dimensional adjectives, spatial feature terms) because our prior findings showed that spatial language used to describe "where" objects were located in space was highly correlated with overall language use whereas this was not the case for spatial language used to describe spatial features of objects (Pruden et al., 2011).

Another important question concerns contexts most conducive to exposing children to rich spatial language. It is important to determine whether differential engagement in spatial activities (block and puzzle play) accounts for parents' differential use of spatial language with boys versus girls (Dearing, Casey, Ganley, Tillinger, Laski & Montecillo, 2012; Jirout & Newcombe, 2015; Levine et al., 2012; Verdine, Golinkoff, Hirsh-Pasek, Newcombe, Filipowicz & Chang, 2014). If this were the case it would suggest that increasing children's, particularly girls', engagement in spatial activities would not only increase their opportunities to engage in spatial thinking but also their exposure to spatial language. As it currently stands, boys are more likely to play with blocks than girls (Kersh et al., 2008; Petersen & Levine, 2015). However, if block play and the spatial language that accompanies block play are important to building spatial skills, all children should be encouraged to engage in this kind of play. Studies suggest spatial play and language go hand-in-hand (Ferrarra et al., 2011; Ramani, Zippert, Schweitzer & Pan, 2014), and both contribute to spatial thinking development (Fisher, Hirsh-Pasek, Newcombe & Golinkoff, 2013; Levine et al., 2012; Peterson & Levine, 2015). Thus, it is possible that by encouraging spatial play, spatial thinking will be supported, not only by play itself, but also by the spatial language heard. In view of the documented importance of spatial thinking for STEM achievement, this approach holds promise for increasing STEM diversity.

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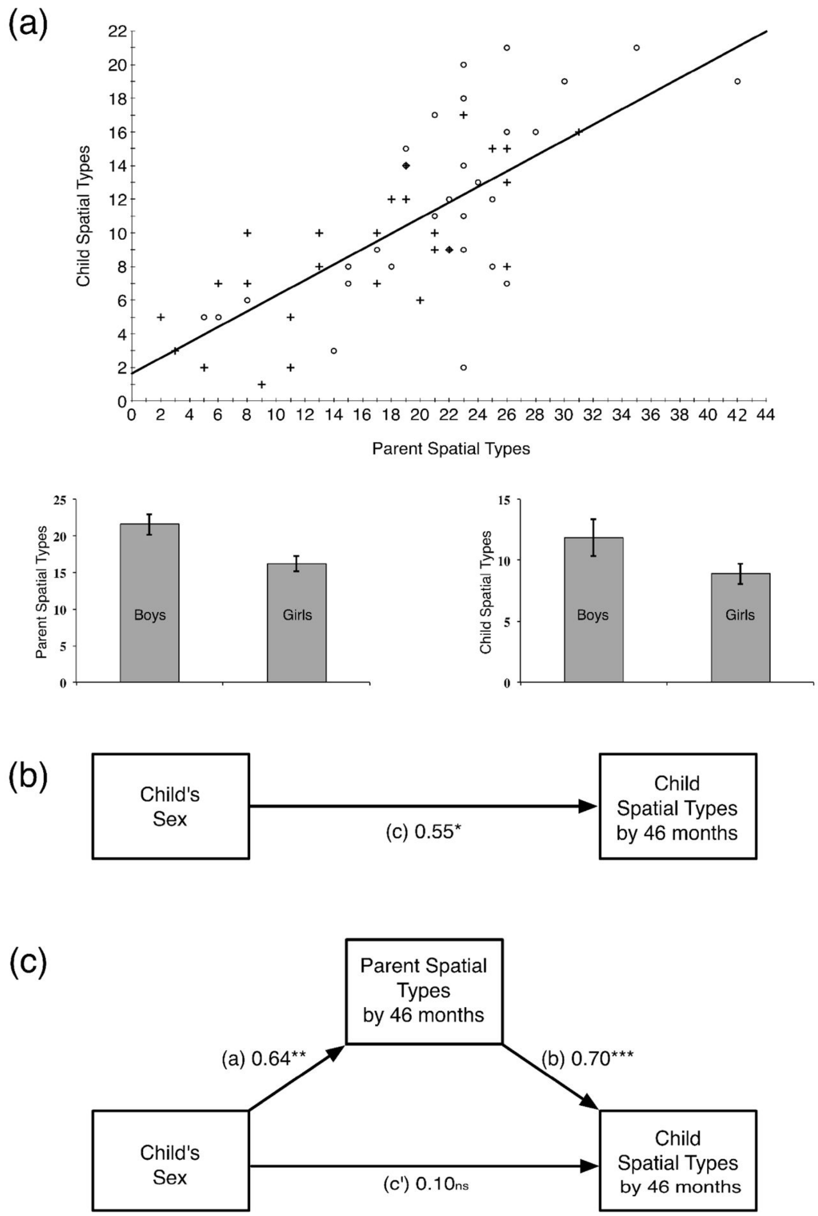

Figure 1.

Scatter plot and bar graphs (1a) showing: (1) the relation between parent ‘*spatial types’* by 46 months and child ‘*spatial types*’ by 46 months. °represent data points for boys; ✚ represent data points for girls (top graph; $r = 0.73$, $p \leq .001$), (2) the relation between child sex and parent ‘*spatial types*’ by 46 months (left bar graph; $r = 0.33$, $p \leq .01$) and (3) the relation between child sex and child *‘spatial types’* by 46 months (right bar graph; $r = 0.29$, $p \leq .05$). The mediation analysis reveals that the direct effect (c) of child sex on child *‘spatial types’* (1b) is no longer significant when parent’s *‘spatial types’* are included as a potential mediator (1c; c'). These results suggest that parent ‘*spatial types’* account for the sex differences in children’s ‘*spatial types*.’ Adj. $R^2 = .5136$ ($n = 57$, β = Standardized regression coefficient, $^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$).

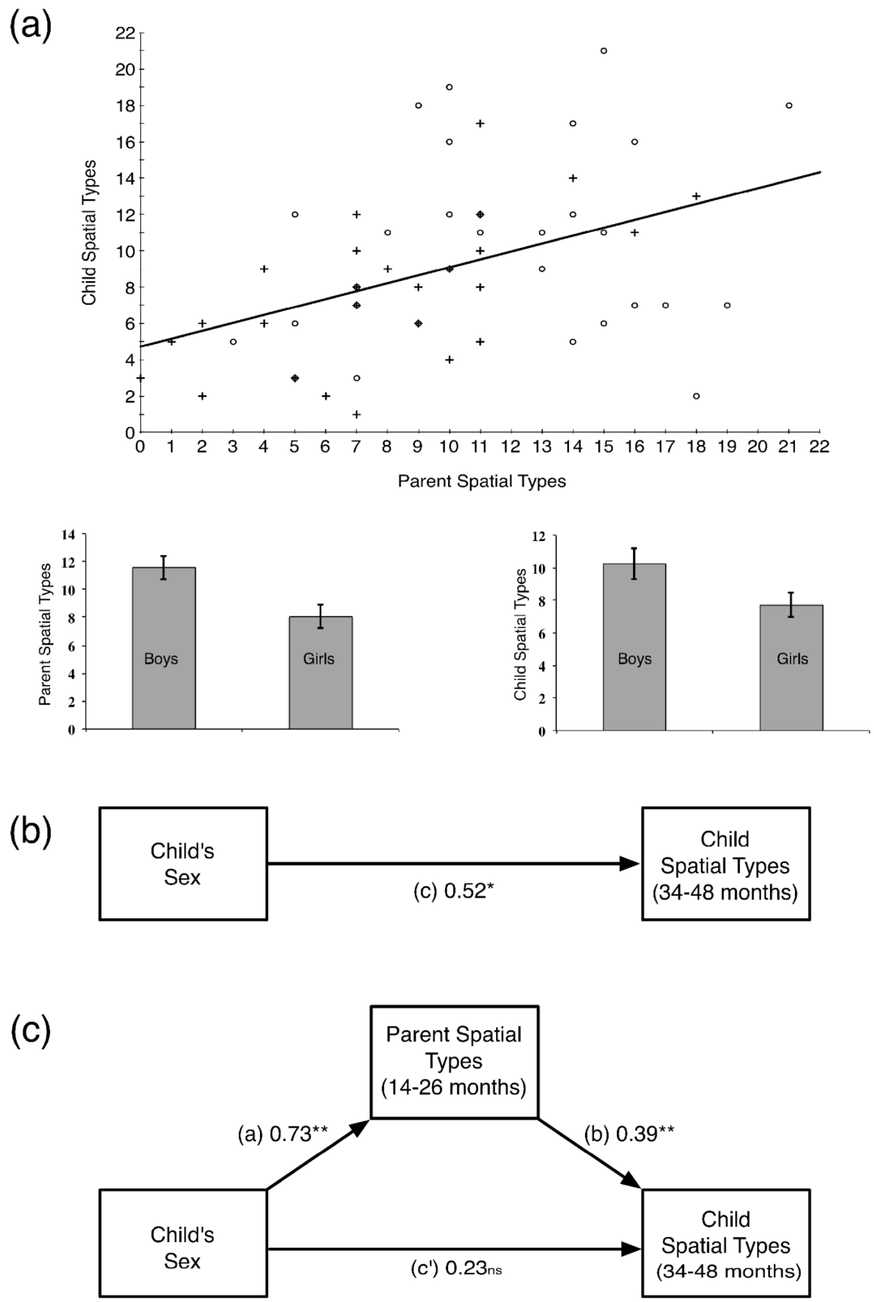

Figure 2.

Scatter plot and bar graphs (1a) showing: (1) relation between parent '*spatial types*' between 14 and 26 months and child '*spatial types*' between 34 and 46 months. °represent data points for boys; ✚ represent data points for girls (top graph; $r = 0.44$, $p \leq .001$), (2) the relation between child sex and parent '*spatial types*' by 46 months (left bar graph; $r = 0.37$, $p \leq .01$) and (3) the relation between child sex and child '*spatial types*' by 46 months (right bar graph; $r = 0.26$, $p \leq .05$). Mediation analysis revealed the direct effect (c) of child sex on child '*spatial types*' (1b) is no longer significant when parent's '*spatial types*' are included as a potential mediator (1c; c'). These results suggest that parent '*spatial types*' accounts for the sex differences in children's '*spatial types*.' Adj. $R^2 = .1742$ ($n = 57$, β = Standardized regression coefficient, $^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$).

Table 1

Demographic Information

		Race/Ethnicity				
		White (not Hispanic)	**Black**	**Hispanic or Latino**	**Multi-Racial**	**Total**
Income	Less than $15,000	0	2	0	0	2
	$15,000–$34,999	3	3	0	1	7
	$35,000–$49,999	2	3	3	0	8
	$50,000–$74,999	6	0	2	1	9
	$75,000–$99,999	9	2	0	1	12
	$100,000 or more	15	1	1	3	20
	Total	35	11	6	6	58

Note. Income of the families can change over the course of the longitudinal project. These data reflect income information of the families from their most recent visit.

Table 2

Descriptive Statistics for Child Language Production by 46 Months

Children's Language Production				
	M	***SD***	***Minimum***	***Maximum***
Boys				
Spatial Types	11.83	5.50	2	21
Spatial Tokens	79.47	50.60	8	191
Other Types[1]	753.17	225.22	322	1213
Other Tokens[1]	10890.20	4372.05	2761	19663
Girls				
Spatial Types	8.89	4.41	1	17
Spatial Tokens	57.93	37.75	2	136
Other Types[1]	736.81	183.60	387	1101
Other Tokens[1]	11160.15	4515.58	3712	22310

Note.

[1]"Other types" included all other word types besides spatial types. "Other tokens" included all other word tokens besides spatial tokens.

Table 3

Descriptive Statistics for Parent Language Production by 46 Months

	Parent's Language Production			
	M	***SD***	***Minimum***	***Maximum***
Boys				
Spatial Types	21.57	7.66	5	42
Spatial Tokens	210.57	137.06	10	525
Other Types[1]	1380.97	366.72	637	2103
Other Tokens[1]	35484.57	15414.12	8196	71926
Girls				
Spatial Types	16.19	7.87	2	31
Spatial Tokens	110.67	82.84	5	322
Other Types[1]	1210.30	327.05	566	1784
Other Tokens[1]	23796.96	9951.06	6009	43186

Note.

[1]"Other types" included all other word types besides spatial types. "Other tokens" included all other word tokens besides spatial tokens.

Table 4

Mediation Results With Covariates Entered Into Analysis

Covariate	*a* path			*b* path			*c* path			*c′* path			R^2_{ad}
	β	*t*	*p*	*β*	*t*	*P*	*β*	*t*	*p*	*β*	*t*	*p*	
Child ‘Other Types’	0.61	2.80	*p*=.0072	0.50	5.14	*p*≤.001	0.50	2.65	*p*=.0107	0.20	1.17	*p*=.25	0.6303
Family SES	0.53	2.52	*p*=.0149	0.69	5.94	*p*≤.001	0.47	2.02	*p*=.0485	0.10	0.52	*p*=.61	0.5048
Total Length of Language Recording	0.59	2.41	*p*=.0196	0.68	6.75	*p*≤.001	0.48	1.99	*p*=.05	0.09	0.45	*p*=.65	0.5160
Birth Order of Child	0.61	2.41	*p*=.0196	0.70	7.04	*p*≤.001	0.51	2.00	*p*=.05	0.08	0.47	*p*=.67	0.5065
Primary Caregiver Gender	0.61	2.40	*p*=.0199	0.71	7.19	*p*≤.001	0.56	2.16	*p*=.035	0.20	0.69	*p*=.4911	0.5089