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Parents' Spatial Language Mediates a Sex Difference in Preschoolers' Spatial Language Use

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Abstract

Do boys produce more terms than girls to describe the spatial world—that is, dimensional adjectives (e.g., *big, little, tall, short*), shape terms (e.g., *circle, square*), and words describing spatial features and properties (e.g., *bent, curvy, edge*)? If a sex difference in children's spatial-language use exists, is it related to the spatial language that parents use when interacting with children? We longitudinally tracked the development of spatial-language production in children between the ages of 14 and 46 months in a diverse sample of 58 parent-child dyads interacting in their homes. Boys produced and heard more of these three categories of spatial words, which we call "what" spatial types (i.e., unique "what" spatial words), but not more of all other word types, than girls. Mediation analysis revealed that sex differences in children's spatial talk at 34 to 46 months of age were fully mediated by parents' earlier spatial-language use, when children were 14 to 26 months old, time points at which there was no sex difference in children's spatial-language use.

Keywords

spatial language, sex differences, preschool children, parental input, longitudinal study

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Research shows that males are better than females at mentally transforming objects and 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, Hansen, & Newcombe, 2013; Levine, Huttenlocher, Taylor, & Langrock, 1999; Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005), 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; Pruden, Levine, & Huttenlocher, 2011; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010; Shusterman, Ah Lee, & Spelke, 2011; Verdine, Lucca, Golinkoff, Hirsh-Pasek, & Newcombe, 2016).

In the current investigation, we asked whether there is a sex difference favoring boys in preschoolers' use of spatial language and whether this is attributable to a gender-related difference in parents' 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 et al., 2016).

The Present Study

Using a longitudinal design, we tracked spatial-language production (from 14 to 46 months) in a diverse sample of parent-child dyads. All children's and parents' speech during nine 90-min observation sessions, in which

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Table 1. Distribution of Family Income by Children's Race-Ethnicity

Income per year	White	Black	Hispanic or Latino	Multiracial	Total
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 information is reported from families' last session.

parents were told to do what they normally do, was transcribed, and researchers coded both parents' and children's spatial-language use. We focused on a particular set of spatial words—words describing the size, shape, and spatial properties of spaces and objects (both animate and inanimate). We focused on these spatial words rather than words describing where an object is located in space (e.g., *in, on, far, over, between*), because use of location words is highly correlated (i.e., collinear) with overall language use, whereas this is less the case for spatial terms describing what an object looks like (Pruden et al., 2011). Thus, our focus on "what" spatial words was driven by the practical difficulty of separating effects involving the 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 et al., 2016, for more about "what" and "where" words).

Although parents' spatial-language use may be linked to the differential engagement of boys and girls in spatial activities such as block play, the present study did not focus on contexts of spatial-language use. Rather, our first step was to examine whether there is a sex difference in spatial-language use and exposure. We consider the issue of context in the Discussion section.

The current investigation asked three questions. First, are there sex differences in children's spatial-language use? Second, do parents use more "what" spatial language with boys than with girls? And finally, does parents' spatial-language use mediate the relation between children's sex and children's spatial-language use?

Method

Participants

Our sample consisted of 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, Illinois, area. Parent-child dyads were part of a larger, longitudinal study of children's language development in which 64 families had been recruited for a project examining the relation between parents' input and children's language development. All children were monolingual English speakers. Twenty of the 30 males were firstborn children, and 13 of the 28 females were firstborn children. Six parent-child dyads were not included in the final sample because they had participated in fewer than eight of the nine sessions, which resulted in less opportunity for observation of their spatial-language use.

Families were recruited via an advertisement in a parenting magazine or by a mailing. 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 distribution of family income according to children's race-ethnicity is shown in Table 1.

Primary caregivers' educational backgrounds varied: 8 reported that they had completed high school but had not taken any college courses, 11 reported that they had taken some college courses or had attended a post-high school trade school, 21 reported earning a bachelor's degree, and 18 reported earning a graduate or professional degree (e.g., master's, doctorate). The average income for our sample fell within the $50,000 to $74,999 range. Socioeconomic status (SES) was computed by creating a composite score of the primary caregiver's education level and family income, because a previous principal components analysis on this sample showed that these two variables were weighted equally, and the principal component (i.e., SES composite score) accounted for 72% of the variance in primary caregiver's education level and family income (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 in their homes nine times, once every 4 months starting when children were 14 months old and ending when they were 46 months old. Dyads were videotaped for an average of 90 min during each session. Parents were instructed to do what they ordinarily would do. No toys or specific objects were given to the dyads. A typical session included activities such as playing with toys, reading from books, and eating meals or snacks, but no instructions were given about what activities to engage in. In the event that the parent was engaged in different activities than the child (e.g., the child was playing with toys while the parent was in the kitchen preparing a snack), the research assistant continued to videotape the child.

Coding and reliability

Using the established procedures outlined by Huttenlocher, Vasilyeva, Waterfall, Vevea, and Hedges (2007), trained research assistants transcribed the speech of children and their parents at all nine sessions. To ensure reliability, we selected a random 20% of transcripts and asked a second trained research assistant to independently code 10% of children's utterances. Reliability was assessed at the utterance level; the first and second research assistant agreed on 95% of transcript decisions.

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 all sessions. We also calculated the cumulative use of all other word types and other word tokens. Using the system for analyzing children's language about space (Cannon, Levine, & Huttenlocher, 2007), we coded three categories of "what" spatial words and targeted them for further analysis: shape terms, dimension terms, and spatial-features terms. *Shape* terms are the names of two- and three-dimensional objects and spaces (e.g., *circle, triangle, octagon*, and the word *shape*). *Dimension* terms describe the size of objects, people, and spaces (e.g., *big, little, tall, tiny, small, tall, short*, and *long*). *Spatial-features* terms describe the features and properties of two- and three-dimensional objects, people, and spaces (e.g., *bent, curvy, edge, side, line*, and *corner*). Our coding system identified approximately 100 unique dimension, shape, and spatial-features terms. The first author identified and coded targeted "what" spatial words; when there were questions about the word's usage, the first author and second author together determined 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 spatial-word counts. Examples of excluded words are 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).

Portions of the current data were previously used to examine the relationship between parents' spatial language and children's 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 differences in parents' spatial-language input to boys versus girls, the focus of the current study.

Data analysis

For each child and parent, the number of unique "what" spatial types produced (e.g., *big* and *little* are two unique types of spatial words) and the number of "what" spatial tokens produced (e.g., *big* used 5 times would be counted as five tokens) were calculated across all sessions to yield cumulative spatial-types and spatial-tokens scores. These cumulative totals 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 "what" categories because analysis revealed no interaction between sex and spatial-language category. 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.[1]

We also calculated children's and parents' cumulative other word types and tokens across all sessions by tallying all word types and all word tokens each child and parent had produced and subtracting the number of "what" spatial types and "what" spatial tokens. These variables were used as covariates in the mediation analyses to test whether effects were related to differences in spatial language or to overall language use. However, in cases in which our spatial-language variable was collinear with our overall language variable, as was found with "what" spatial types and other word types, we ran a separate analysis with other word types to determine whether our effects were unique to "what" spatial types and not a product of overall language use.

Observation sessions averaged 90 min at each session (~810 min total) but varied somewhat across dyads (M = 787.65 min, SD = 33.26, range = 679.33–812.40), as a few dyads completed only 8 sessions instead of 9 sessions. Because of this, we controlled for the amount of time over which children were observed in our analyses.

Table 2. Descriptive Statistics for Children's Language Production Across All Sessions

Gender and production category	*M*	*SD*	Minimum	Maximum
Boys				
"What" spatial types	11.83	5.50	2	21
"What" spatial tokens	79.47	50.60	8	191
Other word types	753.17	225.22	322	1,213
Other word tokens	10,890.20	4,372.05	2,761	19,663
Girls				
"What" spatial types	8.89	4.41	1	17
"What" spatial tokens	57.93	37.75	2	136
Other word types	736.81	183.60	387	1,101
Other word tokens	11,160.15	4,515.58	3,712	22,310

Results

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 other talk. We predicted that boys would produce more "what" spatial talk than girls, but there would be no significant difference between the two groups in their amounts of other talk. For all analyses, we used cumulative types and tokens across all sessions and collapsed all three categories of "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 "what" spatial and other word types and tokens across the sessions, as well as standard deviations and ranges, are reported in Table 2. Descriptive statistics for children's language use revealed considerable variability in "what" spatial types and spatial tokens, as well as differences by sex. Not surprisingly, some children used relatively few "what" spatial types and spatial tokens across the sessions, whereas others used substantially more. Moreover, as reported in a previous publication, the spatial language that children produced predicted their spatial skills on nonverbal tasks (Pruden et al., 2011).

Children's production of "what" spatial and other word types. A multivariate analysis of variance (MANOVA) with children's sex as the independent variable and children's word type ("what" spatial, other) as the dependent variable was significant, $F(2, 54) = 3.55$, $p = .04$, $\eta_p^2 = .17$. Planned univariate analyses of variance (ANOVAs) revealed that boys produced significantly more "what" spatial types than girls, $F(1, 55) = 4.91$, $p = .03$, $\eta_p^2 = .08$ (Fig. 1b, right), but did not differ from girls in their production of other word types, $F(1, 55) = 0.89$, $p = .77$, $\eta_p^2 = .002$. This significant sex difference in children's production of "what" spatial types held when we controlled for family SES, $F(1, 54) = 4.076$, $p = .048$, $\eta_p^2 = .07$; time over which language samples were obtained, $F(1, 54) = 3.95$, $p = .05$, $\eta_p^2 = .068$; birth order of the child, $F(1, 54) = 4.007$, $p = .05$, $\eta_p^2 = .07$ (included because some studies have reported effects of birth order on language; e.g., Hoff-Ginsberg, 1998); and parents' gender, $F(1, 54) = 4.68$, $p = .035$, $\eta_p^2 = .08$. There were still no significant differences between boys' and girls' production of other word types even after we controlled for family SES, $F(1, 54) = 0.001$, $p = .988$, $\eta_p^2 < .001$; time during which language samples were obtained, $F(1, 54) = 0.001$, $p = .992$, $\eta_p^2 < .001$; birth order of the child, $F(1, 54) = 0.002$, $p = .965$, $\eta_p^2 < .001$; and parents' gender, $F(1, 54) = 0.002$, $p = .965$, $\eta_p^2 < .001$. These results suggest that the difference in spatial-language production does not just reflect greater talkativeness (i.e., use of other word types) of boys than girls, and they show that the sex difference remained even when we controlled for a variety of covariates.

Children's production of "what" spatial and other word tokens. A MANOVA with children's sex as the independent variable and children's word tokens ("what" spatial, other) as the dependent variable was marginally 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, "what" 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 word tokens, $F(1, 55) = 0.053$, $p = .82$, $\eta_p^2 = .001$. The boy-girl difference in production of "what" spatial tokens remained marginally significant when we controlled 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 parent gender,

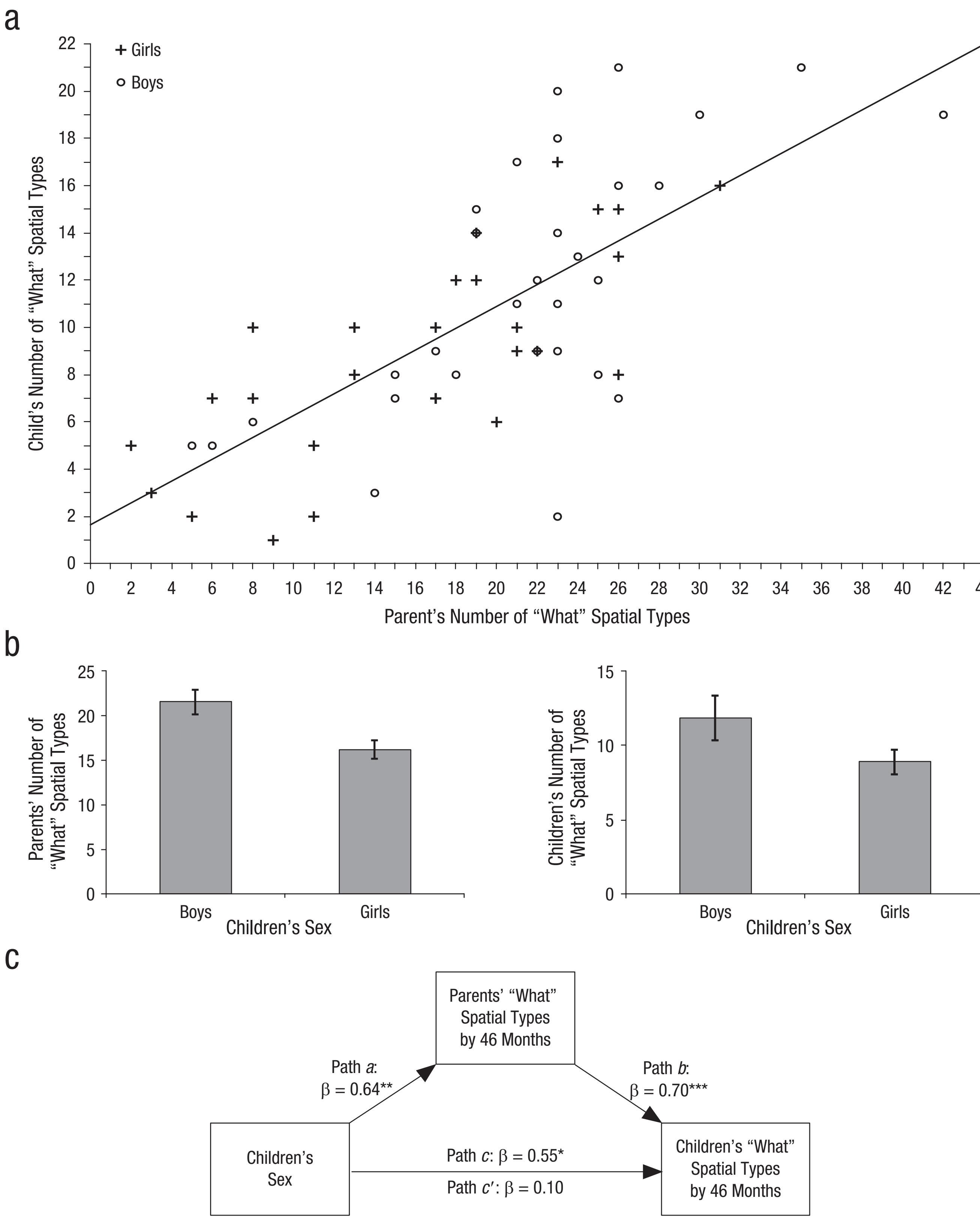

Fig. 1. Results across the nine observation sessions. The scatterplot (with best-fitting regression line; a) shows the relation between the mean number of "what" spatial types each child and his or her parent produced, separately for boys and girls. The bar graphs (b) show the mean number of "what" spatial types produced by parents (left) and children (right), separately for boys and girls. Error bars show ±1 *SEM*. The model (c) illustrates the effect of children's sex on children's production of "what" spatial types, as mediated by parents' production of "what" spatial types. Asterisks indicate significant paths ($^*p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$).

Table 3. Descriptive Statistics for Parents' Language Production Across All Sessions

Gender and production category	*M*	*SD*	Minimum	Maximum
Boys				
"What" spatial types	21.57	7.66	5	42
"What" spatial tokens	210.57	137.06	10	525
Other word types	1,380.97	366.72	637	2,103
Other word tokens	35,484.57	15,414.12	8,196	71,926
Girls				
"What" spatial types	16.19	7.87	2	31
"What" spatial tokens	110.67	82.84	5	322
Other word types	1,210.30	327.05	566	1,784
Other word tokens	23,796.96	9,951.06	6,009	43,186

$F(1, 54) = 2.973$, $p = .09$, $\eta_p^2 = .052$. However, there were still no significant differences between boys' and girls' production of other word tokens even after we controlled for family SES, $F(1, 54) = 0.301$, $p = .585$, $\eta_p^2 = .006$; time during which language samples were obtained, $F(1, 54) = 0.262$, $p = .611$, $\eta_p^2 = .005$; birth order of the child, $F(1, 54) = 0.264$, $p = .610$, $\eta_p^2 = .005$; and parent gender, $F(1, 54) = 0.002$, $p = .966$, $\eta_p^2 < .001$.

Are there sex differences in parents' spatial-language use?

The second aim of the study was to examine whether parents used more "what" spatial and other word types and tokens with boys than with girls. For these analyses, we used cumulative types and tokens across all sessions, again summing over the three categories of "what" spatial words, as the three subcategories of "what" spatial words did not show any significant interactions by sex. In Table 3, we report the mean cumulative "what" spatial and other word types and tokens that parents of boys and girls produced across all sessions, as well as standard deviations and ranges.

Parents' production of "what" spatial and other word types. A MANOVA with children's sex as the independent variable and parents' word types ("what" spatial, other) 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 "what" spatial types when interacting with boys than with girls, $F(1, 55) = 6.83$, $p = .01$, $\eta_p^2 = .11$ (Fig. 1b, left). This difference was still significant when we controlled 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 parent gender, $F(1, 54) = 5.755$, $p = .02$, $\eta_p^2 = .10$. Parents also produced marginally more other word types when interacting with boys than with girls, $F(1, 55) = 3.408$, $p = .07$, $\eta_p^2 = .058$. However, this marginally significant difference was reduced to nonsignificance when we controlled 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 parent gender, $F(1, 54) = 1.84$, $p = .18$, $\eta_p^2 = .033$.

Parents' production of "what" spatial and other word tokens. A MANOVA with children's sex as the independent variable and parents' word tokens ("what" spatial, other) as the dependent variable was significant, $F(2, 54) = 6.05$, $p = .004$, $\eta_p^2 = .18$. Planned univariate ANOVAs revealed that parents produced significantly more "what" spatial tokens with boys than with girls, $F(1, 55) = 10.79$, $p = .002$, $\eta_p^2 = .16$. The significant sex difference in parents' production of "what" spatial tokens held when we controlled 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 parent gender, $F(1, 54) = 9.65$, $p = .003$, $\eta_p^2 = .152$. Parents also used significantly more other word tokens when interacting with boys than with girls, $F(1, 55) = 11.28$, $p = .001$, $\eta_p^2 = .17$. This significant difference held when we controlled 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 parent gender, $F(1, 54) = 8.663$, $p = .005$, $\eta_p^2 = .138$. Given that the sex difference in parents' production of language was not unique to "what" spatial tokens, but also included other word tokens, we focused all further analyses on parents' "what" spatial types.

Table 4. Effects of Including Covariates in the Model of Children's Sex as a Predictor of Children's "What" Spatial Types, as Mediated by Parents' "What" Spatial Types

	Path *a* (Children's sex → parents' spatial types)			Path *b* (Parents' spatial types → children's spatial types)			Path *c* (Total effect: children's sex → children's spatial types)			Path *c*′ (Direct effect: children's sex → children's spatial types)			
Covariate	β	*t*(54)	*p*	β	*t*(54)	*p*	β	*t*(54)	*p*	β	*t*(54)	*p*	Adjusted R^2
Children's other word types	0.61	2.80	.0072	0.50	5.14	≤ .001	0.50	2.65	.0107	0.20	1.17	.2500	.6303
Family SES	0.53	2.52	.0149	0.69	5.94	≤ .001	0.47	2.02	.0485	0.10	0.52	.6100	.5048
Total length of language recording	0.59	2.41	.0196	0.68	6.75	≤ .001	0.48	1.99	.0500	0.09	0.45	.6500	.5160
Birth order of child	0.61	2.41	.0196	0.70	7.04	≤ .001	0.51	2.00	.0500	0.08	0.47	.6700	.5065
Parents' gender	0.61	2.40	.0199	0.71	7.19	≤ .001	0.56	2.16	.0350	0.20	0.69	.4911	.5089

Note: See Figure 1 for an illustration of the basic mediation model. SES = socioeconomic status.

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

The third and final aim of the study was to evaluate whether parents' "what" spatial types mediated the relation between children's sex and children's "what" spatial types (note that we could not carry out this analysis on "what" spatial tokens because a significant difference in the number of "what" spatial tokens that boys and girls produced was a necessary finding for carrying out a mediation analysis; Baron & Kenny, 1986).

To meet the prerequisites of a mediation analysis, we first ran regressions to confirm that there was (a) a significant relation between the predictor variable (children's sex) and outcome variable (children's "what" spatial types), (b) a significant relation between the predictor variable and mediating variable (parents' "what" spatial types), and (c) a significant relation between the mediating variable and the outcome variable (children's "what" spatial types). Once these significant relations were established, we conducted a linear regression with parents' "what" spatial types as a potential mediator between children's sex and children's "what" spatial types. For these analyses, we used the cumulative number of "what" spatial types across all sessions. Regression analysis showed that children's sex significantly predicted children's "what" spatial types, $\beta = 0.55$, $t(55) = 2.22$, $p = .03$, and children's sex significantly predicted parents' "what" spatial types, $\beta = 0.64$, $t(55) = 2.61$, $p = .01$ (Fig. 1c). Finally, parents' "what" spatial types predicted children's "what" spatial types, $\beta = 0.70$, $t(55) = 7.19$, $p < .001$ (Fig. 1c). Thus, the prerequisite relations between all three variables of interest were met for a mediation analysis to be conducted. Figure 1a shows a scatterplot of children's number of "what" spatial types in relation to parents' number of "what" spatial types.

When parents' "what" spatial types were included as a potential mediator, the path coefficient (path *c*′) was significantly reduced and no longer significant, $\beta = 0.10$, $t(55) = 0.51$, $p = .61$ (Fig. 1c). This suggests that parents' "what" spatial types fully mediated the sex difference in children's production of "what" spatial types. A bias-corrected bootstrapping procedure (1,000 iterations; Preacher & Hayes, 2004) provided a 95% confidence interval of −0.81 to −0.08. This interval did not contain zero, which suggests that the reduction in the direct relation between children's sex and children's "what" spatial types was significant. These results suggest that the relation between children's sex and children's "what" spatial types was fully mediated by parents' "what" spatial types, which accounted for the sex difference in children's "what" spatial types. This model accounted for over 51% of the variance (adjusted R^2) in children's production of "what" spatial types.

Our effects held, with the path coefficients retaining the same significance, after we controlled for children's other word types, family SES, length of language transcripts, birth order of the child, and parents' gender in follow-up mediation analyses (see Table 4 for covariates and adjusted R^2s for each model). A potential criticism is that parents' production of other word types could explain the mediation. However, not surprisingly, parents' other word types were highly correlated with parents' "what" spatial types ($r = .81$, $p < .001$, two-tailed). This multicollinearity precludes including both in the same mediation model (Iacobucci, 2008). We did, however, run the same mediation model with parents' other word types as the mediator instead of parents' "what" spatial types. Our expectation was that if parents' language in general was responsible for the sex difference in children's "what" spatial types, then parents' other word types would mediate the relation in the same way as parents' "what" spatial types had.

We found that the relation between children's sex and parents' other word types was not significant, β = 0.48, $t(55) = 1.85$, $p = .07$; however, the relation between parents' other word types and children's "what" spatial types was significant, β = 0.50, $t(55) = 4.49$, $p < .001$, and, as reported previously, the relation between children's sex and children's "what" spatial types was also significant, β = 0.55, $t(55) = 2.22$, $p = .03$. While there was statistically no path for mediation given the lack of a significant path from the independent variable to the mediator, when parents' other word types were included as a potential mediator, the path coefficient was significantly reduced and no longer significant, β = 0.31, $t(55) = 1.41$, $p = .16$. This suggests that parents' other word types may also be a potential mediator of the reported sex difference in children's production of "what" spatial types. A bias-corrected bootstrapping procedure (1,000 iterations) provided a 95% confidence interval of 0.0034 to 0.5164. This interval did not contain zero, which suggests that the reduction in the direct relation between children's sex and children's "what" spatial types was significant. This model accounted for 31% of the variance (adjusted R^2) in children's production of "what" spatial types. These findings leave open the question of whether parents' use of spatial language was a specific predictor of children's spatial language or whether these findings might simply be explained by parents' overall language use with their children. We will return to this issue when we discuss using lagged data to examine whether parents' other word types mediated sex differences in children's "what" spatial types.

We next tested whether children's spatial-language input could explain this effect by testing the reverse causal mediation model in which children's "what" spatial types served as the mediator between children's sex and parents' "what" spatial types. When children's "what" spatial types were included as a potential mediator, the path coefficient was significantly reduced and no longer significant, β = 0.26, $t(55) = 1.41$, $p = .1635$. This suggests that children's "what" spatial types fully mediated the sex difference in parents' production of "what" spatial types. This model accounted for 52.87% of the variance (adjusted R^2) in parents' production of "what" spatial types. This finding suggests that there may be effects of children's production of spatial types on parents' production of spatial types and leaves open the possibility that sex differences in spatial-language production may be driven not by parents but by children, or may 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' spatial-language input could explain the sex difference in children's spatial-language production, we ran an additional mediation model utilizing parents' "what" spatial types produced during the first four sessions (14–26 months) and children's "what" spatial types produced during the last four sessions (34–46 months). This model was less likely to suffer from reverse causal effects (child to parent) and thus allowed us to explore stronger evidence that parents' spatial-language input could explain the sex difference in children's spatial-language production (and not children's production explaining parents' production). In addition, we continued to explore whether parents' other word types might be an alternative plausible mediator of the sex difference in children's "what" spatial types.

We replicated our previous findings utilizing data from four different sessions for children and parents. On average, parents produced 11.57 "what" spatial types ($SD = 4.60$, range = 3–21) with boys and 8.07 "what" spatial types ($SD = 4.36$, range = 0–18) with girls during the early sessions. A MANOVA with children's sex as the independent variable and parents' word types ("what" spatial, other) during the early sessions as the dependent variable was significant, $F(2, 54) = 4.47$, $p = .02$, $\eta_p^2 = .14$. Planned univariate ANOVAs showed that during the early sessions, parents produced significantly more "what" spatial types when interacting with boys than when interacting with girls, $F(1, 55) = 8.61$, $p = .005$, $\eta_p^2 = .14$ (Fig. 2b, left). Moreover, parents did not significantly differ in their production of other word types with boys versus girls during the early sessions, $F(1, 55) = 2.44$, $p = .124$, $\eta_p^2 = .04$, which suggests again that parents did not generally provide more diverse vocabulary with boys than girls during the first 2 years of life. Looking at children's production of "what" spatial types during the later sessions, we found that, on average, boys produced 10.23 "what" spatial types ($SD = 5.16$, range = 2–21), and girls produced 7.74 "what" spatial types ($SD = 3.98$, range = 1–17). A MANOVA with children's sex as the independent variable and children's word types ("what" spatial, other) during the later sessions 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 "what" spatial types than girls at the later sessions, $F(1, 55) = 4.11$, $p = .048$, $\eta_p^2 = .07$ (Fig. 2b, right), but boys and girls did not significantly differ in their production of other word types, $F(1, 55) = 0.24$, $p = .63$, $\eta_p^2 = .004$. These results suggest that even when looking at how parents' "what" spatial types at earlier sessions predicted children's "what" spatial types at later sessions, we found that boys produced significantly more "what" spatial types—but not more other word types—than girls.

We also asked whether boys and girls differed in their production of "what" spatial and other word types during the earliest four sessions. On average, boys

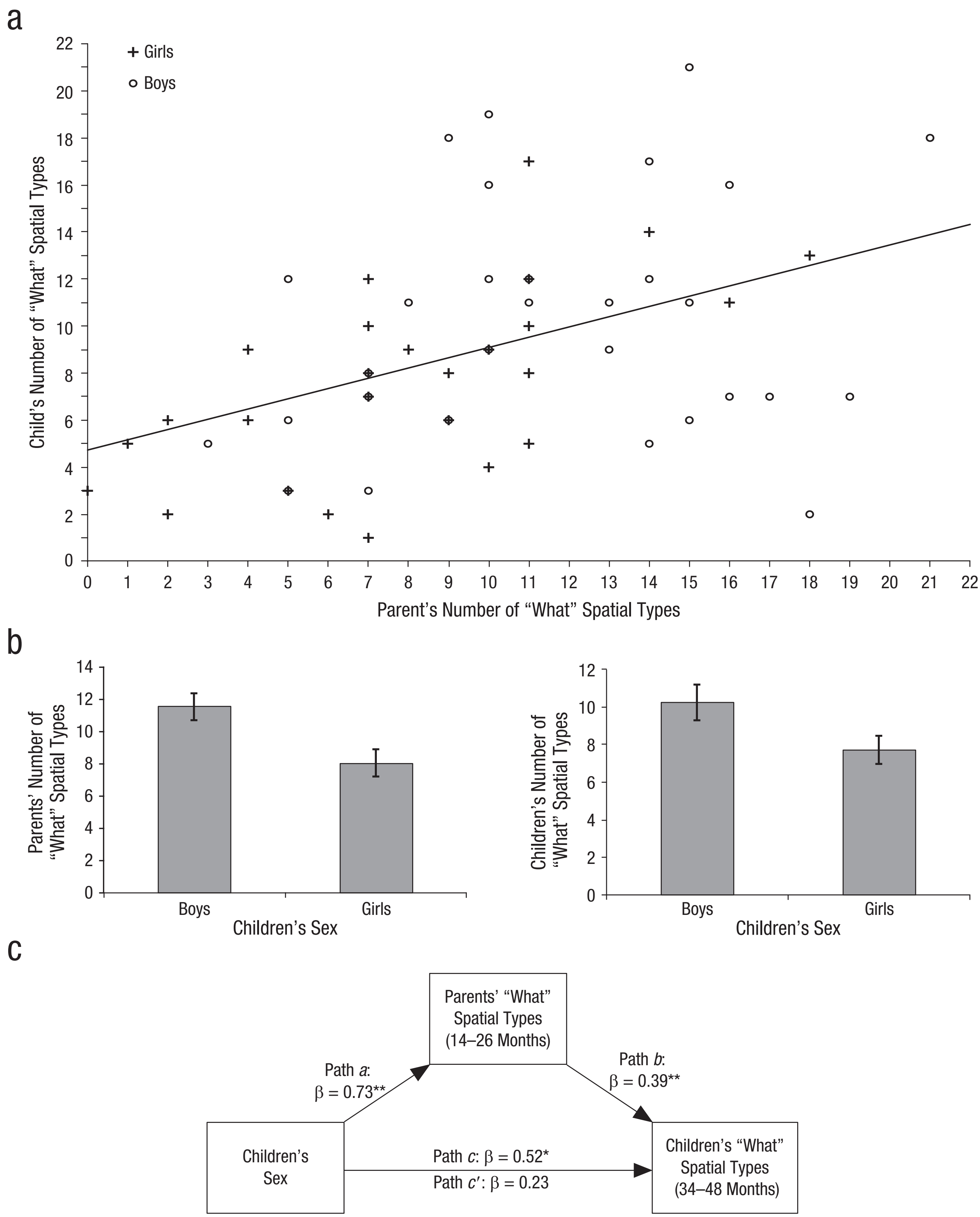

Fig. 2. Results across the first four observation sessions only. The scatterplot (with best-fitting regression line; a) shows the relation between the mean number of "what" spatial types each child and his or her parent produced, separately for boys and girls. The bar graphs (b) show the mean number of "what" spatial types produced by parents (left) and children (right), separately for boys and girls. Error bars show ±1 *SEM*. The model (c) illustrates the effect of children's sex on children's production of "what" spatial types, as mediated by parents' production of "what" spatial types. Asterisks indicate significant paths (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

produced 2.30 “what” spatial types (SD = 2.18, range = 0–8) and girls produced 1.70 “what” spatial types (SD = 1.98, range = 0–7) during the early sessions. On average, boys produced 215.20 other word types (SD = 133.91, range = 6–493), and girls produced 232.07 other word types (SD = 122.20, range = 41–558). A MANOVA with children’s sex as the independent variable and children’s word types (“what” spatial, other) 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 children’s “what” spatial types, $F(1, 55) = 1.16$, $p = .29$, $\eta_p^2 = .02$, or children’s other word types, $F(1, 55) = 0.25$, $p = .62$, $\eta_p^2 = .004$, at these early sessions, which suggests 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 types with boys than with girls at the early or later sessions. This lack of an early sex difference in children’s “what” spatial types also precluded carrying out any further lagged analysis (i.e., early child differences predicting later parent differences).

We next explored whether parents’ greater use of “what” spatial types with boys than with girls at the early sessions provides a plausible explanation for boys’ greater use of “what” spatial types at the later sessions. Figure 2a shows a scatterplot of children’s number of “what” spatial types at the later sessions in relation to parents’ number of “what” spatial types at the early sessions. Regression analysis showed that children’s sex significantly predicted children’s “what” spatial types produced at the four later sessions, $\beta = 0.52$, $t(55) = 2.03$, $p = .0476$, and children’s sex significantly predicted parents’ “what” spatial types using only parents’ “what” spatial types produced at the four early sessions, $\beta = 0.73$, $t(55) = 2.93$, $p = .0049$ (Fig. 2c). Finally, parents’ “what” spatial types at the early sessions predicted children’s “what” spatial types at the later sessions, $\beta = 0.39$, $t(55) = 3.02$, $p = .0039$ (Fig. 2c). When parents’ “what” spatial types produced at the early sessions were included as a mediator, the path coefficient was significantly reduced and no longer significant, $\beta = 0.23$, $t(55) = 0.9084$, $p = .37$ (Fig. 2c), which suggests that parents’ “what” spatial types fully mediated the sex difference in children’s “what” spatial types. The bias-corrected bootstrapping procedure yielded a 95% confidence interval that did not contain zero ([−0.84, −0.03]), which suggests that the reduction in the direct relation between children’s sex and children’s “what” spatial types was significant. This model accounted for 17% of the variance in children’s “what” spatial types.

As with our analysis including all sessions, we wanted to ensure that our finding here was not simply that parents’ other word types at the early sessions was explaining the sex differences in children’s “what” spatial types at the later sessions. As with our previous analysis, we found, not surprisingly, that at the early sessions, parents’ other word types were highly correlated with parents’ “what” spatial types ($r = .72$, $p < .001$, two-tailed), which again reveals that multicollinearity is an issue when using both variables in the same model. Thus, we again ran a separate mediation model with parents’ other word types—instead of parents’ “what” spatial types—during the first four sessions as the mediator.

Contrary to the model that included data from all sessions, this model did not reveal evidence that parents’ other word types at the first four sessions mediated the relation between children’s sex and children’s “what” spatial types at the last four sessions. As in the mediation model that included all sessions, there was no significant relation between children’s sex and parents’ other word types, $\beta = 0.41$, $t(55) = 1.56$, $p = .12$. Similar to the model including all sessions, there was a significant relation between parents’ other word types and children’s “what” spatial types, $\beta = 0.39$, $t(55) = 3.17$, $p = .003$, and the relation between children’s sex and children’s “what” spatial types was also significant, $\beta = 0.52$, $t(55) = 2.06$, $p = .048$. While there was statistically no path for mediation given the lack of a significant path between children’s sex and parents’ other word types, when parents’ other word types were included as a potential mediator, the path coefficient was significantly reduced and no longer significant, $\beta = 0.36$, $t(55) = 1.49$, $p = .14$.

However, unlike in our analysis including all sessions, the bias-corrected bootstrapping procedure (1,000 iterations) provided a 95% confidence interval of −0.0089 to 0.4030, which did contain zero. This suggests that the reduction in the direct relation between children’s sex and children’s “what” spatial types was not significant. This model accounted for less than 19% of the variance (adjusted R^2) in children’s production of “what” spatial types. This mediation model, in conjunction with the model that tested parents’ spatial types as a possible mediator, points to the unique role that parents’ “what” spatial types play in explaining the sex differences in children’s “what” spatial types. These findings with only the first four sessions for parents’ “what” spatial types and the last four sessions for children’s “what” spatial types suggest that parents’ spatial-language input may explain the sex difference in children’s spatial-language production (and not children’s production of “what” spatial types explaining parents’ production of these word types or parents’ production of other word types explaining children’s difference in spatial types).

Discussion

This study addressed two questions. First, is there a sex difference in children's spatial-language production, with boys producing more "what" spatial talk than girls, and second, do parents of boys and girls differ in their spatial-language use with their children, which would potentially explain this sex difference? With regard to our first question, we found a sex difference in the production of "what" spatial language during preschool years, which was significant during naturalistic interactions occurring when children were between 34 and 46 months old, but not earlier. Compared with girls, boys produced more unique "what" spatial words (i.e., dimensional adjectives, shape words, and spatial-features 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 et al., 2013; Pruden et al., 2011).

Our second question, whether parents' 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 are frequency and type of language experiences (i.e., the amount and type of language children hear; Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). Variance estimates suggest that early language input accounts for between 12 and 64% of unique variance in children's later language skills (Walker, Greenwood, Hart, & Carta, 1994). Research has shown that parents' use of specific words predicts children's use of those words. Parents' use of number words with 14- to 30-month-olds predicts children's number talk and their later understanding of the cardinal meaning of number words (Gunderson & Levine, 2011).

Utilizing a longitudinal design, we examined whether parents' use of "what" spatial language mediates the sex difference found in children's use of "what" spatial words. Mediation analyses confirmed that parents' production of "what" spatial types fully mediated the sex difference in children's production of unique "what" spatial words, even when we controlled for a variety of variables. This mediation produced similar results when parents' and children's sessions were contemporaneous (all sessions when children were between the ages of 14 and 46 months) and when they were distinct (parents' "what" spatial types produced when children were between 14 and 26 months old and children's "what" spatial types when they were between 34 and 46 months old). Results suggest that parents' spatial-language input is an important predictor of children's spatial productive vocabularies. Multicollinearity of spatial-language input with other language input precluded our entering both types of parents' language input into the same analysis. However, in our lagged analyses, we found that parents' "what" spatial types mediated the relation between children's sex and children's "what" spatial types, whereas parents' other word types did not. Specifically, the lagged analysis with parents' other word types as the mediator did not meet the statistical prerequisites for mediation. Despite this, we conducted the mediation and found that this variable did not function as a mediator in the same way as parents' "what" spatial types did in our lagged analysis.

One finding was surprising given that previous literature examining spatial-language development (e.g., Pruden et al., 2011) has shown that the quantity of spatial tokens used by parents significantly predicted the quantity of spatial tokens used by children and those children's later spatial skills. Although we found that 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 (the 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 effects for spatial tokens may be a product of our small sample size, and our effect sizes for spatial tokens suggest that this may be the case.

Although the sex difference in the number of unique "what" spatial words that children hear and produce is small, it is potentially meaningful. In a prior study using the same database, we found that children's own use of spatial language in the first 4 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. For example, mental rotation is linked to success in STEM college courses (Wai, Lubinski, Benbow, & Steiger, 2010) as well as to improvement on a number-line task and the ability to solve missing-term problems in elementary school children (Cheng & Mix, 2014; Gunderson, Ramirez, Beilock, & Levine, 2012). Thus, our findings have potential practical implications for efforts to enhance spatial thinking, which has been shown to be a significant predictor of STEM success (Wai et al., 2010).

What contributes to the sex difference that we uncovered in parents' and children's use of "what" spatial language? First, it is possible that children's spatial-language use drives parents' spatial-language use, rather than the reverse. This seems unlikely given that parents provided more "what" spatial language to boys than to girls at early sessions when there was not a significant sex difference in children's use of "what" spatial language. Further, this early difference in parents' usage predicted the later sex difference in children's spatial-language use, whereas the reverse was not true—that is, we did not find that an early sex difference in children's use of "what" spatial language predicted a later sex difference in parents' use of "what" spatial language. However, our correlational findings cannot rule out the possibility of reverse causation or that there is a bidirectional relation between parents' and children's use of "what" spatial language.

Second, it is possible that parents use more "what" spatial language with boys because boys engage more in spatial activities (Cherney & Voyer, 2010; Kersh, Casey, & Young, 2008) 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 nonspatial activities and evidence that boys play more with certain spatial toys than girls do, including blocks (Caldera et al., 1985; Ferrarra, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011; Kersh et al., 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. Relatedly, 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 that this may be the case in contexts of parent-child puzzle play (Levine, Ratliff, Huttenlocher, & Cannon, 2012) 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 (the present study included fathers in only six of the parent-child dyads). 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-features 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 less the case for language used to describe spatial features of the objects themselves (Pruden et al., 2011).

Another important question concerns the 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 than with girls (Dearing et al., 2012; Jirout & Newcombe, 2015; Levine et al., 2012; Verdine et al., 2014). If this were the case, it would suggest that increasing children's, particularly girls', engagement in spatial activities would increase not only 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 are (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 that spatial play and language go hand in hand (Ferrarra et al., 2011), and both contribute to the development of spatial thinking (Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Levine et al., 2012; Petersen & Levine, 2015). Thus, it is possible that by encouraging spatial play, parents will support spatial thinking, not only by how they play but also by the spatial language they use when doing so. In view of the documented importance of spatial thinking for STEM achievement, this approach holds promise for increasing STEM diversity.

Action Editor

Brian P. Ackerman served as action editor for this article.

Author Contributions

S. C. Levine contributed to the design of the larger longitudinal study, the methods for collecting the data, and the coding scheme for the spatial words. S. M. Pruden and S. C. Levine developed the research question for this publication. S. M. Pruden analyzed the data. S. M. Pruden drafted the manuscript, and S. C. Levine provided critical revisions. Both authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Open Practices

The spatial-language coding system used in this research is available for download at http://weww.spatiallearning.org/index.php/resources/testsainstruments and can be requested by e-mailing the authors.

Note

1. When her data were included, the sex difference between boys' and girls' production of "what" spatial types was marginally significant (p = .07). The "what" spatial types and tokens produced by this child's parent were within 2 standard deviations from the mean.

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