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Parental use of spatial language and gestures in early childhood

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Parents' use of spatial language and gestures is closely linked to children's spatial language development. Little is known about the quantity and quality of early spatial input and how infants' individual characteristics may be related to the spatial input they receive. Here, we examine (1) the amount and type of spatial input 16- to 21-month-old Turkish-learning children ($n = 34$) received in the context of a spatial activity (puzzle play) and (2) whether parental spatial input in the form of speech and gesture varies based on children's age, sex, and early spatial vocabulary comprehension assessed in an earlier session. Results of the regression analyses showed that parents' use of spatial words was predicted by children's age over and beyond earlier spatial word comprehension and sex. In particular, parents used more spatial speech as their children got older even in this restricted age range. Children's early spatial word comprehension also correlated with parents' spatial word production. Yet, parents' overall gesture use and gestures with spatial words were not predicted by children's age, sex, or early spatial word comprehension. These findings suggest that in the spatial domain, early verbal input, but not gestural input, can change depending on children's age and children's spatial vocabulary comprehension may also be related to parental use of later spatial language.

Statement of contribution

What is already known on this subject?
- Parents enhance their children's spatial skills using spatial language and gestures.
- Parental spatial talk is related to children's later spatial skills.

What does this study add?
- We assess both spatial talk and gesture in early childhood.
- We examine the children's characteristics (age, sex) in relation to spatial talk and gesture.
- We present how children's earlier vocabulary competence relates to parental input.

Spatial thinking is a crucial factor for STEM (Science, Technology, Engineering, and Mathematics) achievement (e.g., Shea, Lubinski, & Benbow, 2001; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014; Wai, Lubinski, & Benbow, 2009). Spatial language that encodes information about spatial features of objects, their dimensions, or locative relations and actions is closely linked to how we organize our

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spatial thinking (Chatterjee, 2008). Recent studies suggest that parents' use of spatial language and spatial gestures is related to children's spatial language development and their subsequent spatial thinking (Cartmill, Pruden, Levine, & Goldin-Meadow, 2010; Levine, Ratliff, Huttenlocher, & Cannon, 2012; Pruden, Levine, & Huttenlocher, 2011). Yet, less is known about the quantity and quality of early spatial input and how infants' individual characteristics may be in relation to the spatial input they receive. In this study, we examine the parental speech and gesture of Turkish-learning 16- to 21-month-old children in the context of a puzzle play activity. We ask whether child characteristics such as children's age, sex, and early spatial vocabulary comprehension predict parents' use of spatial words and gestures during this age period.

Parental spatial input

Early parental language input is a significant predictor of children's later lexical knowledge. The amount of exposure to different word types and tokens (number of words children heard) is related to children's vocabulary development (e.g., Hart & Risley, 1995; Hoff, 2006; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2008; Weizman & Snow, 2001). Parents also gesture when they interact with their children (e.g., Acredolo & Goodwyn, 1988; Özçalışkan & Dimitrova, 2013; Özçalışkan & Goldin-Meadow, 2010), and gestural input is linked to children's later language abilities (e.g., Iverson, Capirci, Longobardi, & Caselli, 1999). For example, children whose parents gesture to communicate a variety of meanings develop larger vocabularies later (Rowe & Goldin-Meadow, 2009). However, less is known about the specific vocabulary input from parents such as the use of adjectives (Blackwell, 2005), verbs (Goodman, Dale, & Li, 2008; Naigles & Hoff-Ginsberg, 1998), number words (Gunderson & Levine, 2011), and spatial words (Levine *et al.*, 2012). In this study, we examine parents' use of spatial input and how it is related to children's characteristics.

Spatial language provides categorical labels in a continuous space, and thereby creates boundaries in the environment and highlights the patterns that might otherwise be unnoticed (Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011; Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2012). For example, using a preposition such as *next to* or *near* to describe where a puzzle piece should be moved can help the child detect the relationship between two puzzle pieces.

Recent studies suggest that similar to the overall vocabulary input, parental spatial talk is associated with children's later spatial vocabulary knowledge (Pruden *et al.*, 2011). Parents' spatial language accompanied by gestures is also related to children's use of different spatial words (Cartmill *et al.*, 2010). Gesture can be helpful for parents to communicate about space as it represents gradient information better than speech (e.g., So, Shum, & Wong, 2015). For example, making a flat closed hand to represent a flat object can capture the shape of the object and direct child's attention to the spatial word that marks that spatial property. Thus, parents can enhance their children's spatial skills using spatial language and gestures (Cartmill *et al.*, 2010; Pruden *et al.*, 2011). Parents' use of gestures that accompany spatial language can be helpful for children by directing their attention to the spatial aspects in the environment as well as depicting and thereby highlighting those aspects. Yet, it is also crucial to ask whether child characteristics are related to spatial input given to children.

Child-based factors related to spatial input

Several factors can contribute to the amount and type of input given to children. Demographic factors such as socio-economic status (SES) are related to the variability in parental verbal input (e.g., Hart & Risley, 1995; Hirsh-Pasek *et al.*, 2015; Hoff, 2003, 2006; Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Rowe, 2008). In addition, parents with higher SES use a variety of gestures to communicate more than parents with lower SES (Rowe & Goldin-Meadow, 2009).

Children's age becomes another important factor that influence child-directed input (e.g., Bellinger, 1980; Huttenlocher *et al.*, 1991; Rowe, Pan, & Ayoub, 2005; Snow, 1972). For example, parents increase both the amount of talk and the type of vocabulary directed to children between 14 and 36 months of age (Rowe *et al.*, 2005; see also Huttenlocher *et al.*, 1991). On the other hand, there are inconclusive results on parents' use of gestures based on children's age. By analysing gestures of Italian mothers in a longitudinal study, Iverson *et al.* (1999) found that parents produced comparable amount and types of gestures when children were between 16 and 20 months of age. Similarly, the average gesture tokens and types as well as speech utterances accompanying gestures remained stable across six time points when children were between 14 and 34 months of age (Rowe, Özçalışkan, & Goldin-Meadow, 2008). In contrast to these findings, in a recent cross-sectional study testing children of 8–10, 12–14, 18–20, and 24–26 months of age, Crowe (2016) showed that parents could modify their overall gesture use based on the child's age, particularly for conventional gestures.

Given the female advantage in language development for the first 3 years (Huttenlocher *et al.*, 1991), children's sex might be another factor that is related to the quality and quantity of parental input in speech and gesture. Some studies show that mothers talk more to their daughters than sons (e.g., Cherry & Lewis, 1976; Leaper, Anderson, & Sanders, 1998) and use fewer descriptive statements to their daughters than sons in toddlerhood (O'Brien & Nagle, 1987). Yet, others reveal no difference in parental input for different sexes (e.g., Huttenlocher *et al.*, 1991). On the gesture side, there are not many studies that examine this issue. The one study that analysed parents' speech + gesture combinations did not find any difference in parents' gesture frequency based on the sex of the child (Özçalışkan & Goldin-Meadow, 2010).

Parents' spatial input in language and gesture might also be related to contextual factors and/or children's characteristics. Parents produce more spatial talk during block play or puzzle play compared to other everyday interactions (Ferrara *et al.*, 2011; Levine *et al.*, 2012). Moreover, Levine *et al.* (2012) found that the quality of parent–child dyads' puzzle play measured by a composite score of puzzle difficulty, parental engagement, and parental spatial language was higher for boys than for girls between 26 and 46 months of age. However, the individual measures including parental spatial language did not differ between boys and girls. In a very recent study, Pruden and Levine (2017) demonstrated that compared to girls, boys hear more 'what' spatial words referring to the properties of objects such as shape and size of objects. In addition, parents' use of 'what' spatial types mediated the sex difference in children's production of 'what' spatial types.

Taken together, parental overall input as well as spatial input can be influenced by child-based factors. Nevertheless, the results are not conclusive on several aspects. First, previous studies did not analyse how child-based factors such as age and sex would be related to gesture production of parents in spatial contexts. Second, parent–child interaction can change depending on the needs and demands of children (Tamis-LeMonda, Kuchirko, & Song, 2014). Hence, for spatial input, one candidate could be children's knowledge of spatial vocabulary. If parents know that their children understand the terms they use, they

would produce more of a specific type of vocabulary. None of the previous studies examined whether children's earlier vocabulary knowledge, particularly spatial vocabulary knowledge, can be a predictor for parents' later spatial-verbal and gestural input.

The current study

The present study extends the literature by examining the quantity and quality of early spatial-verbal and gestural input and how children's individual characteristics can be in relation to the spatial input. We ask (1) what type of spatial input 16- to 21-month-old Turkish-learning children receive in the context of a puzzle play and (2) whether parental spatial input varies as a function of children's age, sex, and early vocabulary knowledge, by keeping SES level constant across families. Turkish is similar to English in terms of spatial vocabulary use, with some cross-linguistic differences such as using the same word *üzeri* for *over* and *above.* For this study, these cross-linguistic differences do not matter as we only assess Turkish-speaking parents and general spatial input rather than focusing on a certain type of spatial input (for language-specific spatial distinctions in Turkish, see Allen *et al.*, 2007; Arik, 2009). To identify the spatial words, we used an adapted version of the System for Analyzing Children's Language About Space (Cannon, Levine, & Huttenlocher, 2007; Pruden *et al.*, 2011) and categorized the spatial words and phrases in three categories: (1) '*what*' terms (the size, shape, or features of objects and people such as small, triangle), (2) '*where*' terms (information about locations or directions of objects, or transformation of objects and people such as near, under, turn, and deictic words such as there), and (3) *motion and spatial-verbs* such as insert and jump.

First, we predict that spatial language use of parents will vary by the age of children. More specifically, the older the children (even in this restricted age group), the more spatial-verbal input they will receive. Before and after 18 months of age, children's language competence varies and parental input can be related to this variation. On the basis of the previous studies of the amount of gestures children receive (e.g., Iverson *et al.*, 1999; Özçalışkan & Goldin-Meadow, 2010), we expect that children's spatial gestural input will remain similar across this age period. Second, due to having limited or mixed evidence on parental input depending on the sex of the child, we do not have specific predictions about parental verbal spatial input directed to different sexes. However, based on the finding about the overall gesture use of parents of different sexes (Özçalışkan & Goldin-Meadow, 2010), we predict no difference in the amount of spatial gestural input (i.e., gestures that accompany spatial words; from now on, we will use the term 'spatial gestures' to refer to these gestures) directed to different sex groups. Third, we expect that children's earlier comprehension of spatial terms (assessed by parental report) will be related to the amount and type of spatial input they receive in both verbal and gestural modalities. Spatial language includes many relational terms such as prepositions and verbs. Thus, we use children's comprehension of relational words from Turkish Communicative Development Inventory-1 (TCDI-I) for children's spatial language comprehension.

Method

Participants

The final sample consisted of 34 parent–child dyads (19 girls, 15 boys). This sample was part of a larger longitudinal language study conducted in Istanbul, Turkey, in which 58

families participated. Families of the present study were of high SES background with all parents having at least a college degree. In the current study, 34 parent–child dyads who participated at two time points were considered: At Time 1, children were 12–15 months old (M_{age} = 14.57, SD_{age} = 1.35), and at Time 2, they were 16–21 months old (M_{age} = 18.86, SD_{age} = 1.52). These ages were specifically chosen to assess spatial input at a very early age, when children start producing their first words. At around 18 months of age, children's vocabulary production seems to increase notably (e.g., Hoff, 2006). Yet, before and after 18 months of age, children show great variation in terms of language competence, and parental input is related to this variation (Hoff, 2006). Therefore, it is important to investigate spatial input at an age range that covers before and after the vocabulary spurt. Additional data from one parent–child dyad were discarded, as the duration of the puzzle play session at Time 2 was less than 1 min.

Materials

At Time 1, parents filled out the TCDI-I (Aksu-Koç *et al.*, 2011), which is a Turkish adaptation of the original MacArthur-Bates Communicative Development Inventory. TCDI-1 was normed on children aged 8–36 months and was used to evaluate communicative behaviours and vocabulary in children based on parental report. TCDI-1 consists of two parts: (1) Vocabulary Checklist (418 items) and (2) Actions and Gestures (69 items). Vocabulary Checklist includes separate sections that constitute relational words: 95 verbs (e.g., come, go, put, show, take) and 10 prepositions (e.g., in, on, under, here, behind) (see Table 1).

At Time 2, parents and children were presented a puzzle to play with. This wooden puzzle toy contained pieces of different size and patterns that depicted the body parts of bears (head, torso, legs) (see Figure 1).

Procedure

At Time 1, parents filled up the TCDI-1. At Time 2, parent–child dyads were given a wooden puzzle toy to play either in a quiet room at children's kindergarten or in the laboratory. Before the play session started, the experimenter demonstrated to the parent and the child how to play with the puzzle, by fitting pieces into the wooden puzzle board,

Table 1. Means and standard deviations of Turkish Communicative Development Inventory measures for Time 1

	Mean (*SD*)	Median	Min	Max
Comprehension				
Total word	135.53 (82.47)	120.50	22	392
Verb	46.71 (34.31)	41.50	3	121
Preposition	5.21 (4.93)	3.50	0	17
Relational words	51.93 (38.96)	44.00	3	136
Production				
Total word	25.68 (21.13)	24.50	1	81
Verb	1.96 (3.64)	0	0	15
Preposition	0.12 (0.33)	0	0	1
Relational words	2.09 (3.77)	0	0	16

Figure 1. The puzzle used in the study. [Colour figure can be viewed at wileyonlinelibrary.com]

and initiated the free play session by leaving the game area. Each session ended either with experimenter's prompt at the end of 3 min or when children stopped being engaged with the activity and left the game area. Thus, even though a parent–child dyad could interact with the puzzle for 3 min, the sessions varied across dyads (M = 186.53, SD = 81.94, range = 70–377 in seconds). During a typical play session, parents aimed at engaging their children to play with the toy by talking, gesturing, drawing attention to the game area, and playing with the puzzle. All play sessions were recorded for later transcription and coding of speech and gestures.

Coding

Speech

We first transcribed parents' speech during the parent–child interactions in the puzzle play setting. All speech transcriptions were undertaken twice, and conflicts were fully resolved. The number of words produced during a session was counted, which provided a measure of overall language use. Furthermore, in line with our main hypotheses, parents' on-task speech was coded for spatial words and phrases as a measure of spatial parental input. We used an adapted version of the System for Analyzing Children's Language About Space (Cannon *et al.*, 2007), an English coding manual, to identify and categorize spatial words and phrases in Turkish. Even though there were more categories in the English manual, based on Pruden *et al.* (2011) and Turkish spatial word use, we grouped spatial words and phrases under three major categories: (1) '*what*' *terms* that encoded information about the size, shape, or features of objects and people (e.g., *büyük* 'big', *çember* 'circle', *kenar* 'edge'); (2) '*where*' *terms* that included words conveying information about locations or directions of objects (e.g., *yanında* 'next to', *altında* 'under'), orientation or transformation of objects and people (e.g., *çevirmek* 'turn'), or deictic words (e.g., *orada* 'there', *burada* 'here'); and (3) *motion and spatial-verbs* (e.g., *koşmak* 'run', *sokmak* 'insert').

We assessed both *spatial tokens* and *spatial types* for each of these categories. For spatial tokens, we calculated the number of all spatial words used by parents. For spatial

types, we calculated the number of unique spatial words used by parents. Words or phrases were considered as of the same type, if the suffix that was causing the change did not alter the spatial information conveyed. For example, '*yanındaki*' (the one next to) and '*yanındakini*' (the one next to) were of a single type, as the suffix '-i' did not provide novel spatial information. The number of spatial tokens and spatial types was separately assessed for the three spatial language categories. In addition, a cumulative score of spatial language use was assessed separately for both spatial tokens and spatial types, including all three spatial language categories.

Gesture

Parents' spontaneous gestures were transcribed for each parent–child interaction in the puzzle play setting. Both gesture tokens and gesture types were counted. For the number of *gesture tokens*, the total number of gestures produced by parents was counted. These gesture tokens included (1) *deictic gestures*: indicating a referent in the immediate environment by index or palm pointing; (2) *iconic gestures*: bearing a formal similarity to the referent; (3) *beats*: random hand flicks (McNeill, 1992); and (4) *holding gestures*: showing an object by manually holding it. For the number of *gesture types*, the unique gestures for different referents were counted. Each gesture was coded for its meaning, and a given gesture would have a unique type if it had a unique meaning. For example, a point at a puzzle piece was assumed to mean puzzle piece and a point at the wooden puzzle board was assumed to mean puzzle board. These two gestures represented different gesture types because of the different meanings they conveyed. We also counted the number of spatial and non-spatial gestures: spatial tokens in speech that were uttered with or without a gesture. For example, when gesture accompanied a spatial word in speech, the parent would point to a specific puzzle piece by saying 'put it in here'. In such case, as the word 'here' is a spatial word, the gesture accompanying 'here' was coded as a spatial word with gesture (see Table 2 for examples of spatial speech and gesture coding).

Table 2. Examples of parental speech and gesture coding

Speech	Speech coding	Gesture	Gesture coding
Şimdi koy. Şimdi **(1. buraya)** koy. Bak şöyle **(2. çevirip)** deneyelim mi? [*Now put. Now put it **(1. here)**. Look, shall we try **(2. rotating)** it*]	1. Spatial-where, deictic 2. Spatial-verb	1. Index finger pointing at the location of the puzzle 2. Making a circular movement with index finger to depict rotation	1. Deictic 2. Iconic
Bak bu **(1. büyükmüş)** ama biraz daha **(2. küçük)** varmış. Onları bulalım, mesela **(3. bunun gibi)** [*Look, this one is **(1. big)** but there are **(2. smaller)** ones. Let's find them **(3. like this one)**?*]	1. Spatial-what 2. Spatial-what	1. Index finger pointing at the big puzzle piece 2. Holding a small piece of puzzle and showing it to the child 3. Holding another piece of puzzle and showing it to the child	1. Deictic 2. Holding 3. Holding

Reliability

For both speech and gesture measures, two independent coders carried out the coding process. Twenty per cent of the data were coded by two coders: The per cent agreement for speech coding was 94% for parent speech types and 100% for parent speech tokens. For gestures, the per cent agreement for gesture identification (whether there was a gesture or not) and gesture category (deictic, iconic, holding, beat) was 89.36%, and for gestures with spatial referents (spatial words with gestures), it was 90.97%.

Results

Parental spatial words and gestures during puzzle play: Descriptive statistics

The mean number of words parents used was 248 (SD = 122.81, range = 69–603). In a session, parents also produced an average of 26.76 gestures that included deictic, iconic, beat, and holding gestures (SD = 18.41, range = 4–66). Gestures were composed of mostly deictic and holding gestures (71%), then beat (25%) and iconic gestures (4%). The number of words parents produced during a session positively correlated with the total number of gestures they produced within that session, $r(34)$ = .74, p = .001 (see Table 3 for correlations between variables).

We then counted the token/type of spatial words produced by parents. On average, parents produced 27.26 spatial words (SD = 18.85, range = 2–73) (see Appendix for the list of spatial types parents produced). Among these spatial words, parents mainly produced spatial tokens referring to 'where' information (M = 19.82, SD = 12.38), then 'what' information (M = 5.47, SD = 8.35), and motion/spatial-verbs (M = 1.97 SD = 2.71). They also used different *types* of 'where' (M = 8.44, SD = 4.15), 'what' (M = 1.35, SD = 1.73), and motion/spatial-verbs (M = 1.00, SD = 1.23). As the duration (in seconds) of the play sessions varied largely across different parent–child dyads (M = 191, SD = 79), all the type and token measures were divided by the duration of the play sessions. The rest of the analyses were carried out by these corrected scores (see Table 4 for means and SDs as well as corrected means and SDs equivalent to 1-min period).

We carried out a repeated-measures ANOVA to find out differences in the amount of spatial-what, spatial-where, and spatial-verb tokens. The results showed that there was a main effect of spatial tokens parents produced, $F(2, 32)$ = 61.14, $p < 0$, η_p^2 = .65. Pairwise comparisons showed that parents used more where tokens than what and verb tokens, $t(33)$ = 7.47, $p < .001$, and $t(33)$ = 9.02, $p < .001$, respectively. Parents also produced more what tokens than verbs, $t(33)$ = 2.29, p = .028.

We also ran a repeated measures ANOVA to find out differences in the spatial speech types parents used. The results showed that there was a main effect of spatial type parents produced, $F(2, 32)$ = 66.21, $p = 0$, η_p^2 = .81. Pairwise comparisons showed that parents used spatial-where types more than spatial-what types and spatial-verbs, $t(33)$ = 10.63, $p < .0001$, and $t(33)$ = 11.64, $p < .0001$, respectively. No difference was found between spatial-what types and spatial-verbs, $t(33)$ = −0.147, p = .884.

Predicting parents' speech

We conducted hierarchical linear regression models taking parental overall speech, parental use of spatial speech, and parental spatial speech types as outcome variables. Each model included four predictor variables, three of which were T1 age, sex, and T2 age. We used T1 TCDI overall word comprehension (Model 1) or T1 TCDI relational word comprehension (Model 2) for specific analyses as the fourth predictor. The total word

Table 3. Intercorrelations between variables

	T2 age	Sex	T1 overall word comprehension	T1 relational word comprehension	T2 parent total words	T2 parent spatial words	T2 parent total spatial types	T2 parent total gestures	T2 parent spatial gestures	T2 parent spatial gesture types
T1 ag	.826**	.072	.165	.244	.325	.364*	.324	.056	.197	−.082
T2 age	—	−.114	.181	.083	.410*	.485**	.326	.059	.068	−.090
Sex		—	−.062	.189	−.084	.039	.288	.237	.272	.320
T1 overall word comprehension			—	.516**	.169	.234	.038	.008	.011	.107
T1 relational word comprehension				—	.259	.306	.265	.129	.147	.290
T2 parent total words					—	.480**	.299	.446**	.187	.244
T2 parent spatial words						—	.574**	.379*	.333	.401*
T2 parent total spatial types							—	.112	.257	.234
T2 parent total gestures								—	.743**	.739**
T2 parent spatial gestures									—	.683**
T2 parent spatial gesture types										—

Note. *Correlation is significant at the .05 level (two-tailed). **Correlation is significant at the .01 level (two-tailed).

Table 4. Means and standard deviations of all measures during the puzzle play sessions. The left column presents raw scores and the right column presents adjusted raw scores for duration (i.e., token and type measures in 1 min)

	Raw scores				Adjusted raw scores (1 min)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Parental input								
Word tokens	248.00	122.81	69.00	603.00	80.29	24.51	14.68	137.22
Gesture tokens	26.76	18.41	4.00	66.00	8.55	4.54	1.27	20.41
Gesture types	5.26	3.88	0.00	14.00	1.67	0.98	0.00	4.02
Spatial input								
Spatial tokens	27.26	18.86	2.00	73.00	8.63	4.75	0.43	20.50
With gesture	6.65	6.50	0.00	22.00	2.05	1.73	0.00	5.57
Without gesture	20.62	15.35	1.00	56.00	6.57	4.48	0.43	20.50
'What' tokens	5.47	8.24	0.00	33.00	1.41	1.88	0.00	6.29
'Where' tokens	19.82	12.38	2.00	49.00	6.57	3.83	0.43	20.50
'Verb' tokens	1.97	2.71	0.00	12.00	0.65	0.98	0.00	4.29
Spatial types								
Spatial types	10.79	5.65	2.00	22.00	3.65	1.82	0.43	7.71
'What' types	1.35	1.74	0.00	6.00	0.37	0.43	0.00	1.28
'Where' types	8.44	4.16	2.00	18.00	2.91	1.38	0.43	6.00
'Verb' types	1.00	1.23	0.00	3.00	0.37	0.58	0.00	2.57

comprehension was included in the analyses to test the hypothesis that only total relational word comprehension was related to parents' spatial talk. In all analyses, we used the comprehension scores rather than production scores from TCDI due to less number of spatial words produced by children. Below we present regression results for three outcome variables.

Parents' overall speech
The final Model 1 was not significant, indicating that parents' overall speech could not be predicted by child-related factors (R^2 = .18), $F(4, 27)$ = 1.19, p = .128. We next performed the same analyses, this time for the Model 2. The final regression model was marginally significant (R^2 = .18), $F(4, 27)$ = 2.68, p = .053 (see Table 5). We investigated which factors might have contributed in explained variance. In the first step, we have entered T1 age and sex that did not significantly contribute to explained variance (F-change $(2,29)$ = 2.73, p = .08). Adding T1 relational word comprehension again did not result in significant increase in the explained variance (F-change $(3,28)$ = 1.52, p = .23). Finally, we entered T2 age in the model. Although there was no significant F-change $(4,27)$ = 3.07, p = .09, this final model was marginally significant, R^2 = .18, $F(4, 27)$ = 2.68, p = .053. T2 age was the only predictor approaching marginal significance, β = .53, $t(27)$ = 1.75, p = .09. There was a trend that parents produced more speech to older children than younger children.

Parents' spatial speech
For Model 1, the final regression model was not significant (R^2 = .27), $F(4, 27)$ = 2.47, p = .068, and none of the predictor variables were significant. Yet, for Model 2, the final

Table 5. Summary of regression analysis of parents' overall speech as outcome variable. The predictor variables are T1 age, sex, T1 relational word comprehension, and T2 age

| Step	ΔR^2	*F*-change	*SE* (β)	β	*t*	*p*
1	0.16	2.73				
T1 age			0.37	0.37	2.20	.03
Sex			−0.17	−0.17	−1.02	.31
2	0.04	1.52				
T1 age			0.32	0.32	1.88	.07
Sex			−0.21	−0.21	−1.22	.23
T1 relational word comprehension			0.22	0.22	1.23	.23
3	0.08	3.07				
T1 age			−0.14	−0.14	−0.43	.67
Sex			−0.12	−0.12	−0.71	.48
T1 relational word comprehension			0.27	0.27	1.56	.13
T2 age			0.54	0.54	1.75	.09

model was significant, $R^2 = .33$, $F(4, 27) = 3.13$, $p = .02$ (see Table 6). In the first step, T1 age was a significant predictor, $\beta = .36$, $t(29) = 2.11$, $p = .044$; however, the model was not significant, $F(2, 29) = 2.22$, $p = .12$. When included in the model, T1 relational comprehension did not significantly contribute to explaining the variance, *F*-change $(1,28) = 1.83$, $p = .18$. However, in the final step when T2 age was included, the model became significant in explaining 32% of the variance, $F(4, 27) = 3.13$, $p = .02$. The only significant predictor was T2 age, $\beta = .71$, $t(27) = 2.40$, $p = .024$. This result indicated that parents of older children used more spatial speech than parents of younger children, regardless of their T1 relational word comprehension. However, T1 relational word comprehension was approaching significance, $\beta = .31$, $t(27) = 1.86$, $p = .07$, in the final model. There was a trend that T1 relational word comprehension might also contribute to how parents adjusted their spatial speech at T2 (see Figure 2).

We also ran Model 1 taking three different spatial speech tokens (spatial-what, spatial-where, and spatial-verbs) as outcome variables. None of the regression equations were significant for what, where, and verb tokens, $R^2 = .18$, $F(4, 27) = 1.56$, $p = .214$, $R^2 = .26$, $F(4, 27) = 1.392$, $p = .265$, and $R^2 = .03$, $F(4, 27) = 0.238$, $p = .914$, respectively. When we ran Model 2 for the same outcomes, the model was significant only for spatial-where tokens and T2 age was the only significant predictor, $R^2 = .32$, $F(4, 27) = 3.141$, $p = .030$, $\beta = .59$, $t(29) = 2.82$, $p = .009$. For spatial-what and spatial-verbs, the models were not significant, $R^2 = .15$, $F(4, 27) = 1.233$, $p = .320$, and $R^2 = .31$, $F(4, 27) = 0.373$, $p = .825$, respectively.

Parents' spatial speech types
Next, we performed hierarchical regression taking parents' spatial speech types as the outcome variable. Neither Model 1 nor Model 2 was significant, $R^2 = .04$, $F(4, 27) = 1.29$, $p = .299$, and $R^2 = .10$, $F(4, 27) = 0.78$, $p = .547$, respectively.

We also repeated the three regression analyses taking spatial types for what, where, and verbs as outcome variables. Model 1 was significant only for spatial-what types, $R^2 = .31$, $F(4, 27) = 3.021$, $p = .035$, where only T1 age was a significant predictor, $\beta = .59$, $t(29) = 1.89$, $p = .046$. For spatial-where types and spatial-verbs, the models
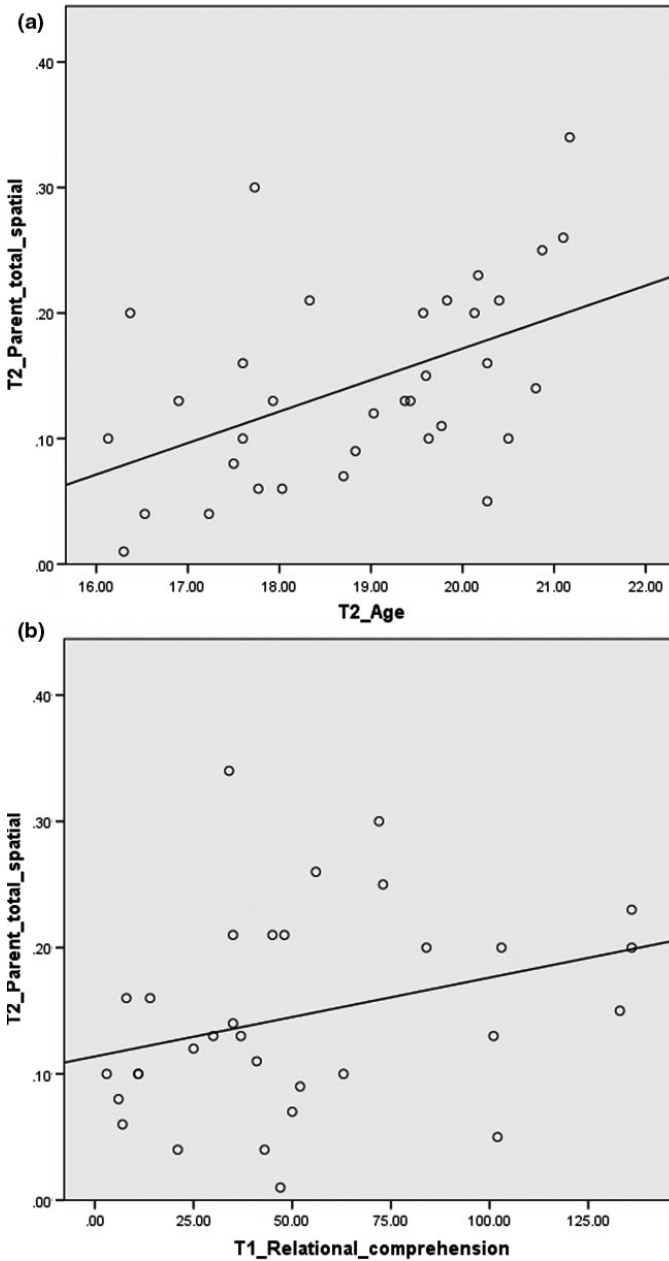
Figure 2. Scatterplots for (a) T2 parent spatial speech (token) and T2 child age and (b) T2 parent spatial speech (token) and T1 child relational word comprehension.

were not significant, $R^2 = .31, F(4, 27) = 1.293, p = .298$, and $R^2 = .31, F(4, 27) = 0.862$, $p = .499$, respectively. When we ran Model 2 for the same analyses, similar results were obtained. Again the model was significant only for spatial-what types where T1 age was the significant predictor, $R^2 = .31$, $F(4, 27) = 3.024$, $p = .035$, $\beta = .59$, $t(29) = 1.92$, $p = .043$. For spatial-where and spatial-verbs, the models were not significant, $R^2 = .11, F$ $(4, 27) = 0.849, p = .507$, and $R^2 = .31, F(4, 27) = 0.581, p = .679$, respectively.

Table 6. Summary of regression analyses of parents' spatial speech tokens as outcome variable. On the left column, the predictor variables are T1 age, sex, T1 overall word comprehension, and T2 age. On the right column, the predictor variables are T1 age, sex, T1 relational word comprehension, and T2 age.

Step	Left predictor	ΔR²	F-change	SE (β)	β	t	p	Right predictor	ΔR²	F-change	SE (β)	β	t	p
1		0.13	2.22						0.13	2.22				
	T1 age			0.01	0.37	2.11	0.04	T1 age			0.01	0.37	2.11	0.04
	Sex			0.27	−0.02	0.12	0.90	Sex			0.27	−0.02	0.12	0.90
2		0.03	1.82						0.19	1.84				
	T1 age			0.01	0.34	1.90	0.07	T1 age			0.01	0.31	1.77	0.09
	Sex			0.03	−0.01	−0.03	0.97	Sex			0.03	−0.60	−0.35	0.73
	T1 word comprehension			0	0.18	1.01	0.32	T1 relational comprehension			0	0.24	1.36	0.19
3		0.10	2.47						0.33	5.75				
	T1 age			0.02	−0.17	−0.54	0.59	T1 age			0.02	−0.30	−0.99	0.33
	Sex			0.03	0.09	0.56	0.57	Sex			0.03	0.06	0.33	0.75
	T1 overall word comprehension			0	0.16	0.95	0.35	T1 relational word comprehension			0	0.31	1.86	0.07
	T2 age			0.02	0.60	1.96	0.06	T2 age			0.02	0.71	2.40	0.02

Predicting parents' gesture use

To investigate how parents' gesture production was related to children's characteristics, we conducted hierarchical linear regression models taking parents' overall gesture use, parents' total spatial gesture use, and parents' use of spatial gesture types as outcome variables. As in the speech analyses, the models included four predictor variables: T1 age, sex, T2 age, and T1 language comprehension. We again used either T1 TCDI overall word comprehension scores (Model 1) or T1 TCDI relational word comprehension scores (Model 2) as the fourth predictor variable.

Parents' overall gesture use

The final Model 1 was not significant in explaining parents' overall gestures, $R^2 = .08$, $F(4, 27) = 0.63$, $p = .645$.

Parents' spatial gesture use

We performed two hierarchical linear regression analyses. Neither Model 1 nor Model 2 was significant in explaining parents' total spatial gesture use, $R^2 = .12$, $F(4, 27) = 0.458$, $p = .645$, and $R^2 = .12$, $F(4, 27) = 0.947$, $p = .452$, respectively. We also investigated whether parents used spatial speech more with accompanying gestures or without gestures. A paired-samples t-test result showed that parents produced spatial speech without gestures ($M = 0.11$, $SD = 0.07$) more often they do with gestures ($M = 0.03$, $SD = 0.03$), $t(34) = -5.442$, $p < .0001$.

Parents' spatial gesture types

Next, we performed hierarchical regression taking parent's spatial gesture types as outcome variable. We again performed two hierarchical linear regression analyses. Again, neither Model 1 nor Model 2 was significant in explaining parents' spatial gesture types, $R^2 = .25$, $F(4, 27) = 2.25$, $p = .090$, and $R^2 = .19$, $F(4, 27) = 1.59$, $p = .206$, respectively.

Discussion

This study examined the quantity and quality of early spatial-verbal and gestural input of parents and how children's individual characteristics were related to the parental spatial input. We asked two main questions: (1) What type of spatial input did 16- to 21-month-old Turkish-learning children receive in a puzzle play situation? and (2) Did parental spatial input differ based on children's age, sex, and early spatial (relational) vocabulary knowledge? Overall, our results suggested that only children's age predicted parental spatial-verbal input. However, parents' use of gestures did not differ depending on children's age. Second, child's sex was not a predictor of any type of spatial input produced by parents. Last, children's earlier relational vocabulary comprehension assessed by parents may also be related to parental use of later spatial language.

Only a few studies investigated parental input in speech and gesture in the spatial domain (Cartmill *et al.*, 2010; Levine *et al.*, 2012; Pruden & Levine, 2017; Pruden *et al.*, 2011). Children's individual characteristics that relate to the amount and quality of parental input directed to children have been studied even less (see Pruden & Levine, 2017). The current study shows that from very early on children's age can be a predictor of

the amount, but not the type, of parental verbal input they receive. The only exception is that parents produced more spatial types referring to 'where' information as children get older, probably due to the nature of the task. Even at this early age range, older children received more verbal spatial input from parents. Parents might be modifying their spatial talk even within this restricted age range, because they might assume that in the context of puzzle play, older children would understand more about the spatial properties or locations and directions of objects.

For the gestural input, children's age did not influence parents' frequency of gesture use. This finding is in line with the earlier research, which found that parents produced similar number and types of gestures when their children were between 16 and 20 months of age (Iverson *et al.*, 1999) or between 14 and 34 months of age (Rowe *et al.*, 2008). Earlier studies did not present whether gestural input with spatial words varied by children's age (Cartmill *et al.*, 2010). We show that parents' gestural input with spatial words did not vary for children between 16 and 21 months of age. Due to representational gestures' advantage at communicating spatial information better than verbal channel, parents could also produce gestures to capture the visual–spatial properties of objects and direct child's attention to the spatial words regardless of children's age. Similarly, pointing gestures that accompany spatial words can help children attend objects or spatial properties of objects. It is also possible that these gestures can help parents to formulate their spatial thinking and talk about spatial information (So *et al.*, 2015). Thus, these gestures might serve a cognitive rather than a communicative function for the parent.

In our study, child's sex was not a predictor of spatial language input. In a previous study, Levine *et al.* (2012) found that only a composite score of puzzle difficulty, parental engagement, and parental spatial language was higher for boys than for girls between 26 and 46 months of age. When they analysed the measures separately, parental spatial language did not differ between boys and girls. In a recent study, Pruden and Levine (2017) examined only 'what' spatial types and found an advantage for boys receiving more of this category of spatial words than girls. Furthermore, as in Özçalışkan and Goldin-Meadow's (2010) findings for parents' equal number of gesture use to both sexes, parents produced similar amount of gestures referring to spatial words to their sons and daughters. Puzzle playing frequency was also found to be similar between boys and girls (Baenninger & Newcombe, 1995). Thus, for puzzle play, parents do not necessarily behave in line with stereotypes for boys and girls as in block play or video games (Levine *et al.*, 2012), and as a result, parents may not use differential input in verbal and gestural modalities before children reach 2 years of age.

Our last predictor variable was children's earlier comprehension of spatial vocabulary. Our findings showed that children's early spatial vocabulary comprehension marginally predicted parents' later use of spatial words. There was a correlation between these variables when we controlled for age ($r(28) = .34$, $p = .043$). We also found that parents may actually alter their spatial language based on their children's production of spatial language even after controlling for overall parental speech ($r(27) = .41$, $p = .024$) (see Figure 2). As in the case of overall word production (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010) and conversational skills (Hoff-Ginsberg, 1990) of children, parents may change their spatial speech based on their children's spatial language comprehension. However, this finding is correlational and we need to investigate the relation between children's understanding of spatial vocabulary and parents' production of spatial language in further studies.

Our findings also contribute to understanding the relation between spatial language and spatial thinking. Several studies have shown that spatial language helps spatial

thinking and performance on many spatial tasks (e.g., Dessalegn & Landau, 2008; Loewenstein & Gentner, 2005; Miller, Patterson, & Simmering, 2016). Analysis of parental verbal and gestural spatial input and how children's individual characteristics relate to the quantity and quality of this input offers us venues to improve children's performance on spatial tasks.

In conclusion, the present study adds to the few research findings on parental input in the spatial domain and shows that the quantity of early spatial input is in close relation to the children's age and can be related to children's spatial vocabulary comprehension. Yet, this study assessed the changes of parental spatial-verbal and gestural input in a restricted age range and in a short play session. Future longitudinal research should examine (1) the variations of spatial input in a longer period and (2) how children receiving distinctive input in both spoken and gestural modalities perform in spatial tasks. In this study, children did not produce many words during play sessions. Assessing how children's spatial speech and gestures develop in relation to parental input is also important. Finally, it is also crucial to conduct experiments that manipulate each type of input in a puzzle play setting and measure its relation to children's spatial thinking while taking into consideration the characteristics children bring into the parent–child interaction. Parental support of spatial concept learning is beneficial not only for learning spatial concepts, but also for children's other STEM-related skills such as math achievement (Lombardi, Casey, Thomson, Nguyen, & Dearing, 2017). The results of these studies have a great value as children's spatial thinking predicts success in STEM fields (e.g., Shea *et al.*, 2001; Verdine *et al.*, 2014; Wai *et al.*, 2009).

Acknowledgements

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Appendix

Types of spatial speech used by parents. Words or phrases were considered as of the same type, if the suffix that was causing the change did not alter the spatial information conveyed. Here, we only listed the main word without showing different alterations.

Spatial-What Types:

- Spatial adjectives: büyük [*big*], küçük [*small*], minik [*tiny*]

Spatial-Where Types:

- Locations: altına [*under*], bu yan [*this side*], ortada [*middle*], öbür yan [*other side*], önüne [*in front of*], sağ tarafına [*to the right*], sol tarafına [*to the left*], yan [*side*], yanında [*on the side*], üstüne [*on top of*]
- Orientations/Transformations: döndür [*turn*], çevir [*rotate*]
- Deictics: bu [*this*], burada [*here*], nerede [*where*], şu [*that*], şurada [*there*], orada [*there*]

Spatial-Verbs:

- çıkar [*to take off*], kaldır [*to lift*], oturttur [*to place*], yerleştir [*to fix in*]