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Enhancing parent and child shape talk during puzzle play☆

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ABSTRACT

Shape puzzles offer opportunities for families to talk about geometric concepts, which supports early spatial reasoning. However, puzzle features (i.e., similarity of shapes) may influence the nature of parent-child talk about shapes (e.g., labeling shapes vs. elaborating on shape properties). In this study, 128 dyads of parents and children (ages 30–47 months) completed both Typical and Highly Alignable (HA) shape puzzles. Compared to the HA puzzle, there was more shape labeling during the Typical puzzle; the HA puzzle elicited more elaborative shape talk (particularly comparing and contrasting shapes). Further, the HA puzzle elicited more elaborative shape talk when similar shapes were distributed on different rows rather than arranged side-by-side. Follow-up analyses found the HA puzzles were more difficult for children to complete. Findings suggest that including similar shapes and manipulating the arrangement of shapes may increase the difficulty of puzzles and elicit increased parent support and enhanced parent-child spatial language during puzzle play.

1. Introduction

Children's early experiences with spatial language appear to contribute to their spatial reasoning. For instance, parents' use of spatial words has been linked to children's later spatial skills (e.g., Pruden et al., 2011). Critically, spatial language is more than labeling shapes - it also involves language that describes the spatial features of shapes and objects (e.g., curved, straight, tall, short) and their locations (Cannon et al., 2007). The quality and range of spatial talk that is shared with children may influence children's spatial learning, which has been found to relate to mathematical performance (e.g., Cheng & Mix, 2014; Verdine et al., 2017). Thus, identifying opportunities to elicit and enhance families' spatial language beyond labeling shapes may strengthen children's spatial skills and provide a foundation for later mathematical success.

The materials that parents and children engage with play a role in how they talk about spatial concepts, because the design of spatial toys and puzzles provide differential opportunities to talk about spatial information (e.g., Casasola et al., 2017; Resnick et al., 2016; Verdine et al., 2019). For example, Verdine et al. (2019) showed that offering unfamiliar non-canonical shapes as well as their familiar counterparts (e.g., a long, narrow rectangle alongside a more traditionally proportioned rectangle) increased parent-child talk

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about shapes during a lab-based teaching task compared to when only canonical shapes were available. One possible explanation is that offering multiple exemplars that are different but highly alignable draws attention to both the similarities and differences, eliciting more in-depth parent-child talk (e.g., Gentner & Namy, 1999; Gentner et al., 2016). However, the shape toys most frequently used by families feature familiar, canonical shapes (Resnick et al., 2016), and such materials may limit families' opportunities to engage in more elaborative shape talk beyond labeling shapes.

In the current study we build on previous findings by further examining how the similarity of shapes influences parent-child shape talk. We compare how much parents and children label shapes and elaborate on shape features while completing two kinds of puzzles: a puzzle with only canonical shapes and two versions of puzzles that included both canonical and non-canonical instances of shapes with shared, alignable features. The versions of the highly alignable puzzles either had similar shapes placed side-by-side or in different rows, allowing us to examine whether shape arrangement also affected parent and/or child spatial talk.

1.1. Early spatial reasoning and spatial language

Engaging with family members in spatial activities such as puzzles during the preschool years is predictive of later spatial skills (Levine et al., 2012) and variation in the quality of families' spatial activities may relate to differences in children's spatial skills (Abad, 2018). One mechanism through which spatial activities likely support spatial skills is by engaging children in conversations that use spatial language (Newcombe, 2018). Spatial language includes words describing sizes and dimensions, words describing relative positions and orientations in space, and words to label shapes and objects and describe spatial features and properties of those shapes and objects (Cannon et al., 2007). Spatial language is predictive of spatial and numerical skills (e.g., Bower, Foster, et al., 2020; Gilligan-Lee et al., 2021), and interventions targeting spatial language have resulted in increases in children's spatial thinking (Bower, Zimmerman, et al., 2020; Casasola et al., 2020). Spatial language may facilitate spatial reasoning by enabling children to verbally encode spatial information (e.g., Feist & Gentner, 2007; Miller et al., 2016; Pruden & Levine, 2017) and by increasing their attention to spatial information (e.g., Miller & Simmering, 2018; Miller et al., 2017).

Interactions in the home environment play an important role in children's spatial learning, as parents' use of spatial language with preschoolers is associated with children's spatial language use as well as their skills on spatial tasks such as mental transformation tasks and block building (e.g., Pruden et al., 2011). Of note, there is also substantial variation in the frequency of parent and child spatial talk across families. Moreover, spatial language is more frequent when parents and children are engaging in spatial activities than non-spatial activities (Ferrara et al., 2011). Thus, when children engage in spatial activities with parents and caregivers, this provides opportunities for them to hear and use spatial language, which, in turn, might support their spatial thinking. The question we address here is whether features of a common spatial activity – puzzle play - induce different amounts and kinds of spatial talk.

1.2. Supporting shape knowledge through alignable multiple exemplars

Knowledge about geometric shapes is considered a key element of young children's spatial thinking (Clements & Sarama, 2011) and includes both identifying shapes by name and understanding the defining features of shapes (National Research Council, 2009; van Hiele, 1999). One way to promote learning about geometric shapes is to include multiple exemplars that draw attention to, and allow for elaboration of, the defining features of shapes (e.g., rectangles with different dimensions or typical and atypical triangles; Clements, 2003; Fisher et al., 2013).

A critical factor when considering multiple exemplars is their alignability – shared structure or dimensions between the exemplars that can be matched up (Gentner & Namy, 1999; Markman & Gentner, 1996; McGill, 2002). Children are more likely to learn new words or concepts when provided with multiple examples with alignable differences – differences that emerge from a shared structure or dimension that can be readily aligned and compared (e.g., Gentner & Namy, 1999; Gentner et al., 2007; Gentner et al., 2016; Graham et al., 2010). For example, children more readily learned that the support orientation was the critical element in constructing a stable building when presented with two model buildings that were identical except for the orientation of the brace support compared to when presented with two model buildings that differed on multiple dimensions (Gentner et al., 2016).

Incorporating alignable differences into shape activities may be an effective strategy for enhancing children's learning during joint parent-child activities because comparisons are a natural pedagogical strategy that parents use to explain concepts to children (Sandhofer, 2001; Valle & Callanan, 2006). Further, engaging in activities with knowledgeable partners such as parents or other adults can facilitate children's exploration of alignable differences and enhance their learning. For instance, Christie and Gentner (2010) found that preschoolers benefitted from multiple exemplars only when an experimenter prompted to compare them. Creating alignable differences within puzzles by including multiple exemplars of similar shapes may prompt parents and children to engage in more in-depth shape talk and better support children's conceptual understanding of shapes.

An additional consideration for supporting children's shape learning through comparison is whether the arrangement of alignable exemplars influences parent and child engagement. There is some evidence that the organization of objects facilitates comparisons and influences children's learning. For instance, Strouse and Ganea (2021) found that 3-year-olds benefitted from having similar examples presented side-by-side (or blocked) compared to presented sequentially whereas 4-year-olds benefitted more from sequential presentation of similar shapes. Consequently, in considering how to utilize alignable differences to support learning of shapes, an open question is whether the arrangement of similar shapes (e.g., side by side in the same row versus in different rows) affects adult and child talk about shapes.

1.3. Prior research on parent-child shape interactions

Although cognitive research demonstrates that children benefit from multiple exemplars with alignable differences, many of the shape materials and toys used by families do not include non-canonical shapes and thus have limited opportunities to attend to alignable differences (Resnick et al., 2016). When examining the shapes in readily available geometric materials for children, including sorting toys, apps, and books, Resnick et al. (2016) found that circles, equilateral triangles, and squares were the most frequently depicted shapes in sorting toys, while rectangles, non-canonical quadrilaterals, and polygons with greater than four sides were infrequently represented. Further, none of the shape-sorting toys included non-canonical triangles. Since elaborative talk benefits children's shape knowledge (e.g., Clements, 2003), not including multiple exemplars in shape games and activities might be a missed opportunity for encouraging elaborative shape talk at home.

One study did find general support for the idea that materials with multiple shape exemplars may naturally elicit more frequent or qualitatively different types of parent and child shape talk. Verdine et al. (2019) asked parents to teach their 3-year-olds the names of as many shapes as possible using either two sets of 10 standard shapes or one set of 10 standard shape and another set of 10 shapes that included different exemplars of the same shape categories (e.g., two equilateral triangles vs. one isosceles and one equilateral triangle). Children who engaged with the set that included alternate shape exemplars used more shape words as well as more overall spatial language compared to children who only engaged with the standard shapes. However, parents' spatial language did not vary by condition, opening the question of whether parent spatial talk, which is often correlated with children's spatial talk and spatial skills (e.g., Pruden et al., 2011) can be similarly impacted by the design of spatial activities with and without multiple exemplars.

As noted by Verdine et al. (2019), a limitation of their study is that prompting parents to teach their children about shapes may not reflect the types of naturalistic home-based interactions parents and children engage in. Additionally, Verdine et al. (2019)'s measure of spatial language was broad, including words that referred to dimension, location, and orientation as well as geometric features and properties. An important open question then is how language about spatial features specifically might be impacted by the presence of multiple exemplars in a more naturalistic setting.

1.4. Current study

We sought to explore how parents and their young children talk about shapes when jointly completing shape puzzles and how the similarity and arrangement of available shapes may elicit quantitatively and qualitatively different spatial talk. Identifying the types of materials that elicit the most elaborative spatial talk has implications for the creation of spatial activities that best support child spatial learning over time.

Our primary research question was, how does the inclusion of more similar, alignable shapes based on category membership influence parent and child talk about shapes during a puzzle? We predicted this manipulation would enhance conversations about shapes by producing more utterances that were *elaborative* compared to a typical shape puzzle. That is, a highly alignable puzzle with more similar, and less familiar, shapes would be more difficult to distinguish and merely label, prompting parents and children to describe, define, and compare and contrast the shapes. In contrast, we hypothesized that a typical puzzle containing only familiar, canonical shapes might result in more shape labeling, because it included more readily labelable and distinguishable shapes.

Our second research question asked how the arrangement of highly alignable shapes contributed to the nature of parent-child talk about shapes. We predicted that placing alignable shapes from the same category side-by-side would draw parents' and children's attention to similarities and differences of shape features and would increase elaborative shape talk compared to puzzles where the same shapes were present but were not placed side by side.

2. Method

2.1. Participants

All procedures and protocols for this study were approved by the university's Institutional Review Board prior to recruiting participants. Our sample consisted of 128 parents and 30- to 47-month-old children (50% girls and 50% boys, mean age = 38 months, *SD* = 5). Dyads were recruited from the Chicago area using a departmental database of families willing to participate in research. We recruited 146 dyads from families with a child between 30 and 47 months old and that reported English was spoken in the home at least 75% of the time. Observations of 18 dyads were excluded because: the recording equipment failed (7), the child was older or younger than the desired age range (7), the dyad spoke in a language other than English for most of the interaction (2), there was an error in the puzzle pieces provided (1), or the parent did not consent to video recording (1).

Based on parent report, 51.6% of the children were White, 26.6% were Black, 17.2% were Multiracial, 1.6% were Asian; 1.6% parents selected the option of "other race" for their child, and 1.6% of parents did not report their child's race/ethnicity. Parents in the study included 115 mothers (89.8%) and 13 fathers (10.2%). Based on self-report, 56.3% of parents identified as White, 27.3% Black, 8.6% Multiracial, 3.1% Asian, 0.8% American Indian/Alaskan Native; 2.3% parents selected the option of "other race", and 1.6% did not report race/ethnicity. The majority (80%) of parents had at least a 4-year college degree. Of the remaining parents, 9% had an associate degree or other 2-year undergraduate degree, 5% completed at least 1 year of college, 4% completed high school or had a GED, and 2% did not complete high school.

2.2. Study design and conditions

We used a 2 × 2 mixed design with Puzzle Type as a within-subject factor (Typical Puzzle and Highly Alignable Puzzle) and arrangement of the shapes in the Highly Alignable puzzle as a between-subject factor (Organized vs. Unorganized). The order of the two puzzles (Typical and Highly Alignable) was counterbalanced, resulting in four between-subject groups, with each group receiving two puzzles. We assigned participants to groups using stratified randomization based on child gender (boys, girls) and age (younger = 30–38 months, older = 39–47 months).

Our sample size was determined by an a priori power analysis, based on our analytic plan to compare group differences using ANCOVA. To detect a moderate effect size (f =0.25) with 80% power and an alpha level of .05, we needed a sample of 128 dyads or 32 dyads per condition group. During video coding, it became apparent that three dyads were given the wrong puzzle. Thus, in our final sample 62 dyads received the Organized Highly Alignable puzzle (29 had Typical puzzle first, 33 had Typical puzzle second), and 66 received the Unorganized Highly Alignable puzzle (33 had the Typical puzzle first, 33 had Typical puzzle second).

2.3. Materials

We used three wooden shape puzzles, designed by our research team (see Fig. 1). The Typical puzzle was modeled after a commercially available shape puzzle by the company Melissa & Doug. It included one exemplar for each of nine canonical shapes: circle, oval, triangle, square, rectangle, rhombus, trapezoid, pentagon, and octagon. It should be noted that the rhombus was oriented sitting on its point and would commonly be called a diamond. Thus, the Typical puzzle included shapes that were visually distinct and that had common names.

Our goal for the Highly Alignable puzzles was to elicit more elaborative parent and child shape talk by adding more similar and less familiar shapes that would be more difficult to differentiate based on commonly used shape labels. We included three triangles differing in dimensions and angles – equilateral, scalene, and isosceles. For the quadrilaterals, we included a trapezoid and a rectangle, as in the Typical puzzle, but eliminated the square, and changed the rhombus (i.e., "diamond" in the Typical puzzle) to a parallelogram. Thus, the quadrilaterals in the Highly Alignable puzzles were more visually similar in that they had similar height:width ratios and were arranged to be resting on a horizontal base. For shapes with greater than four sides, we added a hexagon as an intermediary that was more difficult to distinguish from the pentagon and octagon.

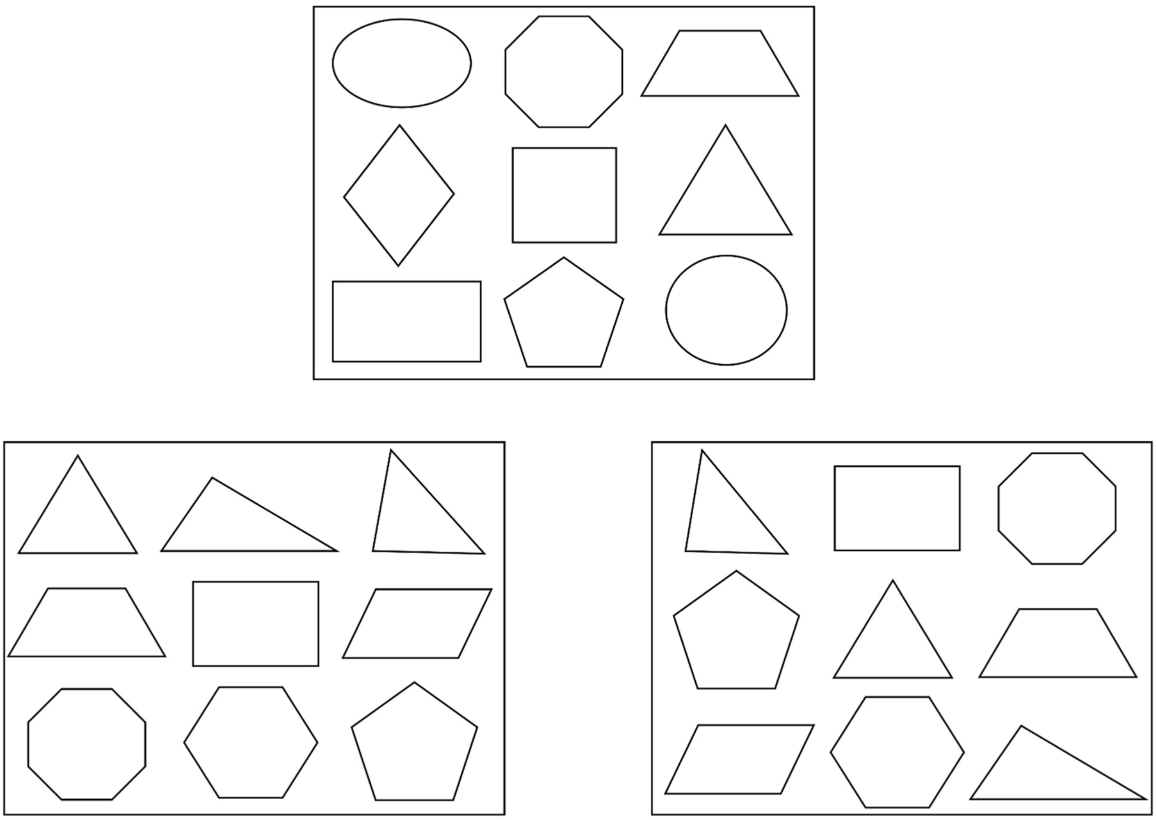

Fig. 1. Illustrations Depicting the Shapes and Alignment on the Typical puzzle (Top) and Organized (bottom left) and Unorganized (bottom right) Highly Alignable Puzzles.

To examine whether visual organization facilitates alignment, we used two different versions of the Highly Alignable puzzles that differed in their arrangement of shapes. The Organized puzzle was arranged by shape category in rows: triangles, quadrilaterals, and polygons with more than four sides. The Unorganized puzzle was arranged so that exemplars were not situated next to shapes of the same category. Thus, each row consisted of a triangle, a quadrilateral, and a polygon with more than four sides. The shape pieces used in the Organized and Unorganized puzzles were identical and all that differed was the arrangement of the pieces.

2.4. Procedure

The study included one 30–45 min session in a university research lab. Following the consent process, dyads played with each puzzle for 6 min, seated side-by-side at a small table. The researcher arranged puzzle pieces on the table outside of the puzzle frame, instructing the dyad to play with the puzzle however they would like. The researcher left the room and returned after six minutes to repeat the procedure for the second puzzle. If a parent or child left the room before six minutes, the researcher would encourage them to continue playing but moved on to the next portion of the study if the parent and/or child indicated that they were finished.

After the interaction, children participated in a 5- to 10-minute spatial assessment activity with the researcher while parents completed a demographic questionnaire and survey in an adjacent testing room. Both the assessment and survey were part of a separate research study and are not discussed in this paper. The puzzle play interactions and spatial assessment were videotaped for later transcription and analysis.

2.5. Transcription and measures of parent and child shape talk

Dyadic interactions were transcribed by a trained research team using the CHAT conventions of the Child Language Data Exchange System (CHILDES; MacWhinney, 2000). All transcripts were verified, or double-checked, by a second member of the research team to ensure the accuracy of intelligible speech and adherence to CHAT conventions. Disagreements were resolved by discussion or by consulting another research team member. Parent and child talk was transcribed into units of utterances, or a sequence of words before or after a pause or a change in conversational turn (Bakeman & Gottman, 1997).

All parent and child utterances were coded for the presence of shape talk, defined as an instance where a speaker labeled or described the shapes (either of the puzzle pieces themselves or spaces for the shapes in the puzzle frame), drew their partner's attention to the shapes, or responded to their partner's talk about shapes. If an utterance was identified as containing shape talk, it was then further coded to categorize the shape talk (see Table 1 for definitions and examples of specific shape talk codes). Coding was mutually exclusive; each utterance identified as shape talk received one shape talk code.

Coding was completed within the CLAN program by three trained coders. To check reliability, 25 transcripts (19.5% of the total transcripts) were coded for shape talk by two coders, with an average Cohen's kappa coefficient of.77. Multiple interpretations of kappa scores support this coefficient as acceptable. According to Cohen (1960), a coefficient between 0.61 and 0.80 would be considered "substantial". Based on a more conservative scale,0.77 would fall at the high end of the "moderate" range (0.60–0.79, McHugh, 2012).

2.6. Measures of child behavior during puzzle play

We also coded children's placement of the puzzle pieces. Using the transcripts and videos, two coders recorded where children tried to place each piece into the puzzle board (e.g., trying to place the triangle piece into the rectangular space). These behaviors were used to create two measures: (1) the total number of errors and (2) the proportion of errors that were within the same shape category (e.g.,

Table 1
Definitions and Examples of Shape Talk Codes.

Shape talk code	Definition	Examples
Shape labeling	Identifying puzzle piece or space by shape label only or prompting to identify shape, without further talk of features, defining characteristics, or relating to other pieces.	"What shape is that?" "Which one is the oval?" "Here is the rectangle."
Elaborative shape talk		
Quantifying sides & vertices	Counting or prompting talk about number of sides or vertices on a given shape without identifying shape by label.	"This one has six sides." "How many sides does this one have?"
Shape descriptors	Describing or prompting talk about shapes features without identifying shape by label.	"Which one is round?" "That shape has a right angle."
Defining	Naming a shape in conjunction with using shape descriptors, properties, or quantifying sides or vertices to define the shape or asking questions focused on linking shape labels with properties.	"Squares have four sides that are all the same length." "How many sides does an octagon have?"
Comparing	Comparing or contrasting multiple shapes (either whole or features) or comparing a shape to a space in the puzzle frame, or prompting comparing or contrasting.	"These are both triangles." "This triangle has a longer side than this one." "All the sides of the square are the same."

triangle placed in another triangle slot). An error was defined as trying to place a shape piece into the incorrect space; only unique errors were counted (i.e., trying to place the triangle in the square space twice would only count as one error). Shape category was defined based on the number of sides (with all polygons with more than four sides being grouped into the same category). The exact number of opportunities for within-category errors differed across the two puzzle types, but there were opportunities for this type of error in both puzzles, and the differences in these opportunities in terms of the similarities between exemplars was a critical component of the intended difference between puzzles.

Although some parents placed some of the pieces, we focus our analysis here on children's behaviors for two reasons. First, in most dyads the child placed most (or all) of the pieces and the parent only provided verbal or gestural scaffolding. Second, our motivation for exploring behavior during puzzle play was to investigate whether children's errors might at least partially explain differences in parents' spatial talk. Two coders coded 20% of the dyads and reliability was high for both the total number of errors (ICC =0.975) and the number of within category errors (ICC =0.953).

2.7. Analytic plan

Initially we planned to compare group differences using ANCOVA. However, the distribution of our outcome measures of parent and child shape talk indicated that our original analytic plan would not be the most appropriate approach. Specifically, shape talk was infrequent and there were many scores of zero, particularly for the elaborative forms of shape talk. We determined that negative binomial regression was the best approach because it predicts the probability of a value for a count variable, allowing the variance to exceed the mean, and is appropriate when there is an overdispersion of count variables (Allison & Waterman, 2012). We ran a series of multilevel negative binomial regression models with observations nested within participants (i.e., parents and children). For each model we included child age, parent education, and child gender as control variables, predicting the frequency of shape talk utterances.

3. Results

3.1. Preliminary analyses and descriptives

Descriptive statistics for dyads' puzzle play are provided in Table 2. The sessions of puzzle play were intended to end after 6 min; despite some variability in the duration of puzzle play, the time spent did not significantly differ among the puzzle types. However, there was variation in how many times dyads completed each puzzle. We defined a round of puzzle play as starting when dyads first picked up a puzzle piece and ending when the final puzzle piece was placed. The average number of rounds was significantly higher for the Typical puzzle than for the Highly Alignable puzzles but did not differ between the Organized and Unorganized Highly Alignable puzzles. During the 6 min, when not completing the puzzle, dyads' behavior was highly variable, ranging from just talking to engaging in elaborate non-puzzle play with the pieces (e.g., building or using the pieces in pretend play). Given this variability, we focus our analyses on the first round of puzzle play only, where dyads were more consistently on-task. In examining time spent on the first round of puzzle play, on average dyads spent more time completing the Highly Alignable puzzles than the Typical puzzle, but time spent on the first round did not differ between the Organized and Unorganized Highly Alignable puzzles.

3.2. Condition differences in parent and child shape talk based on shape similarity

Table 3 reports descriptives for parent and child shape talk during the Typical and Highly Alignable puzzle conditions (summed over Organized and Unorganized Alignable conditions). To examine the effects of puzzle type on parent and child shape talk, we ran negative binomial regression models predicting the frequency of shape talk utterances. In each model we accounted for child age, parent education, child gender, and the order of puzzles (i.e., whether dyads engaged with the Typical or Highly Alignable puzzle first).

Table 2
Dyads' Puzzle Engagement by Puzzle Condition.

Variable	*M* (*SD*)	Range	*M* (*SD*)	Range		Cohen's *d*
	Comparing typical and highly alignable conditions					
	Typical		Highly alignable		*t*(256)	
Total rounds of puzzle play	2.38 (1.16)	1–6	2.13 (0.97)	0–5	2.64 * *	0.23
Total time	6.21 (0.62)	1.13–9.22	6.25 (0.06)	2.53–9.30	0.82	0.06
Time for first round of puzzle play	1.57 (0.80)	0.48–5.52	2.00 (1.05)	0.50–6.97	4.76 * **	0.45
	Comparing highly alignable conditions by arrangement					
	Organized		Unorganized		*t*(128)	
Total rounds of puzzle play	1.98 (0.88)	1–4	2.26 (1.04)	0–5	1.60	0.29
Total time	6.23 (0.83)	2.53–9.30	6.27 (0.38)	4.56–7.15	0.32	0.06
Time for first round of puzzle play	1.99 (1.02)	0.58–6.97	2.00 (1.08)	0.50–6.17	0.04	0.01

Note. Time variables reported in minutes.
* * $p < .01$. * ** $p < .001$.

Table 3
Parents' and Children's Shape Talk During the Typical and Highly Alignable Puzzles.

	Parents				Children			
	Typical		Highly alignable		Typical		Highly alignable	
Shape utterances	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
Shape labeling	7.82 (6.67)	0–27	4.16 (5.11)	0–20	4.55 (4.79)	0–24	2.21 (3.27)	0–15
Total elaborative	1.16 (2.36)	0–15	1.85 (2.97)	0–16	0.41 (1.31)	0–8	0.54 (1.53)	0–12
Describing shape features	0.16 (0.48)	0–2	0.26 (0.72)	0–4	0.03 (0.22)	0–2	0.10 (0.55)	0–5
Comparing shapes	0.19 (0.56)	0–3	0.53 (1.01)	0–4	0.04 (0.29)	0–3	0.09 (0.34)	0–2
Quantifying sides or vertices	0.65 (1.69)	0–12	0.91 (2.05)	0–11	0.34 (1.26)	0–8	0.31 (1.14)	0–9
Defining shapes	0.16 (0.56)	0–3	0.16 (0.49)	0–3	0.00 (0.00)	0	0.02 (0.15)	0–1

3.2.1. *Shape labeling*

We first examined the total utterances where parents were only naming shapes or prompting children to do so and found that parents engaged in significantly less shape labeling during the Highly Alignable puzzle than during the Typical puzzle, IRR [95% CI] = 0.53 [0.39, 0.71]. Parents engaged in 47% less shape labeling during the Highly Alignable puzzle compared to the Typical puzzle when holding all other factors constant (see Table 4). None of the covariates in the model were significantly associated with the amount of parents' shape labeling.

Similarly, we found that children engaged in significantly less shape labeling during the Highly Alignable puzzle than during the Typical puzzle, incidence rate ratio (IRR) [95% CI] = 0.43 [0.32, 0.56]. Children engaged in 57% less shape labeling during the Highly Alignable puzzle compared to the Typical puzzle when holding all other factors constant. Of the covariates in the model, child gender was significantly associated with shape labeling such that girls engaged in 40% less shape labeling than boys, IRR [95% CI] = 0.60 [0.38, 0.93]. Further, when adding an interaction variable (puzzle type x child gender) to the regression model, we found the effect of gender was stronger for the Highly Alignable puzzle, IRR [95% CI] = 0.49 [0.28, 0.85]. There was a greater difference in the shape labeling of boys and girls, with boys engaging in even more shape labeling than girls during the Highly Alignable puzzle, $M(SD)_{\text{boys}} = 3.06(3.60)$ vs. $M(SD)_{\text{girls}} = 1.38(2.69)$, than during the Typical puzzle, $M(SD)_{\text{boys}} = 4.98(5.18)$ vs. $M(SD)_{\text{girls}} = 4.12(4.36)$.

The observed differences in shape labeling between the Typical and Highly Alignable puzzles might stem from the specific shapes included in each puzzle. That is, the Typical puzzle included more unique shape labels than the Highly Alignable puzzle (9 versus 7). However, we calculated the proportion of possible shape labels that parents and children mentioned during the puzzles and found that even after accounting for more unique shape labeling opportunities, there was still significantly more shape labeling during the Typical puzzle. Specifically, parents used a greater proportion of available labels during the Typical puzzle, $M = 0.42$, $SD = 0.33$, than during the Highly Alignable puzzle, $M = 0.26$, $SD = 0.31$; $t(126) = 4.89$, $p < .001$, $d = 0.43$. Children also used a greater proportion of available labels during the Typical puzzle, $M = 0.34$, $SD = 0.33$, than during the Highly Alignable puzzle, $M = 0.16$, $SD = 0.23$; $t(126) = 6.94$, $p < .001$, $d = 0.61$. Finally, examining the total number of shape tokens used (across both labeling and elaborative utterances), we found that parents used more shape tokens when playing the Typical puzzle, $M = 5.37$, $SD = 4.88$, than the Highly Alignable puzzle, $M = 3.16$, $SD = 3.94$; $t(126) = 4.60$, $p < .001$, $d = 0.41$. Similarly, children also used more shape tokens during the Typical puzzle, $M = 3.99$, $SD = 4.07$, than the Highly Alignable puzzle, $M = 1.80$ $SD = 2.77$; $t(126) = 6.66$, $p < .001$, $d = 0.59$. In the Supplemental Analyses, we report shape token comparisons for each individual shape label, with similar findings.

3.2.2. *Elaborative shape talk*

Parents' elaborative shape talk (Table 5), measured as utterances containing shape talk beyond labeling shapes, was significantly higher during the Highly Alignable puzzle than during the Typical puzzle, IRR [95% CI] = 1.77 [1.16, 2.71]. Parents engaged in 77% more elaborative shape talk during the Highly Alignable puzzle compared to the Typical puzzle when holding all other factors constant. Of the covariates in the model, higher levels of parent education predicted more frequent parent elaborative shape talk.

As a follow up, we ran negative binomial regressions for individual types of elaborative shape talk (Table 6). The main effect of puzzle type appeared to be driven by a difference in parents' utterances about comparing shapes, IRR [95% CI] = 3.01 [1.64, 5.51]. Parents engaged in about 200% more utterances about comparing during the Highly Alignable puzzles compared to the Typical puzzle when holding all other factors constant. There was not a significant effect of puzzle type for any of the other subtypes of elaborative shape talk.

Given that dyads spent significantly more time on their first completion of the Highly Alignable puzzle than the Typical puzzle, the increased amount of elaborative talk could be attributable to the longer time spent on the puzzle. To investigate this possibility, we ran second models for parents' elaborative shape talk and comparing utterances covarying for the time spent completing each puzzle (see Supplementary Table S2). There was a main effect of time spent on parents' overall elaborative shape talk, IRR [95% CI] = 1.88 [1.36, 2.59], and there was no longer a significant effect of puzzle type, IRR [95% CI] = 1.24 [0.72, 2.14]. However, for parents' utterances involving comparing shapes, there was also a main effect of time spent on the two puzzle types, IRR [95% CI] = 1.61 [1.12, 2.31], but importantly, there was also a main effect of puzzle type when accounting for time spent on the puzzles, IRR [95% CI] = 2.37 [1.36, 2.59].

In examining children's elaborative shape talk (Table 6), we found that there was no significant effect of puzzle type nor were there significant effects of any of the covariates. When adding time spent on each puzzle type to the model, there was still no main effect of puzzle type (see Supplementary Table S3), but there was an effect of child age on children's elaborative shape talk when accounting for

Table 4
Negative Binomial Regressions Predicting Shape Labeling Utterances During Typical and Highly Alignable Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Parents				
Child age	-0.01 (0.01)	0.99 (0.01)	[0.96, 1.01]	0.272
Parent education	0.08 (0.05)	1.08 (0.05)	[0.98, 1.18]	0.116
Child gender- female[a]				
Puzzle- highly alignable	-0.64 (0.15)	0.53 (0.08)	[0.39, 0.71]	< 0.001
Order- typical first	0.25 (0.15)	1.28 (0.19)	[0.96, 1.73]	0.098
Children				
Child age	-0.01 (0.02)	0.99 (0.02)	[0.95, 1.03]	0.629
Parent education	-0.01 (0.08)	0.99 (0.07)	[0.86, 1.14]	0.910
Child gender- female	-0.52 (0.23)	0.60 (0.14)	[0.38, 0.93]	0.023
Puzzle- highly alignable	-0.85 (0.14)	0.43 (0.06)	[0.32, 0.56]	< 0.001
Order- typical first	0.21 (0.23)	1.24 (0.28)	[0.79, 1.93]	0.353

Note. IRR = incidence rate ratio.
[a] Model for parents' shape labeling did not include child gender because including child gender prevented the model from converging.

Table 5
Negative Binomial Regressions Predicting Parent Elaborative Shape Talk Utterances During Typical and Highly Alignable Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Total elaborative talk				
Child age	0.02 (0.02)	1.02 (0.02)	[0.97, 1.07]	0.515
Parent education	0.25 (0.09)	1.29 (0.12)	[1.07, 1.55]	0.007
Child gender- F	0.12 (0.28)	1.12 (0.31)	[0.65, 1.93]	0.672
Puzzle- HA	0.57 (0.22)	1.77 (0.38)	[1.16, 2.71]	0.008
Order- TF	0.39 (0.28)	1.48 (0.41)	[0.86, 2.55]	0.160
Describing shapes				
Child age	-0.05 (0.04)	0.96 (0.04)	[0.88, 1.04]	0.270
Parent education	0.30 (0.18)	1.34 (0.24)	[0.95, 1.89]	0.093
Child gender- F	-0.06 (0.46)	0.94 (0.43)	[0.39, 2.33]	0.891
Puzzle- HA	0.50 (0.34)	1.65 (0.56)	[0.85, 3.21]	0.139
Order- TF	0.95 (0.48)	2.58 (1.25)	[1.00, 6.64]	0.050
Comparing shapes				
Child age	-0.04 (0.03)	0.96 (0.03)	[0.90, 1.03]	0.283
Parent education	0.12 (0.12)	1.13 (0.14)	[0.89, 1.44]	0.327
Child gender- F	0.14 (0.37)	1.15 (0.43)	[0.56, 2.38]	0.696
Puzzle- HA	1.10 (0.31)	3.01 (0.93)	[1.64, 5.51]	0.000
Order- TF	0.44 (0.37)	1.55 (0.58)	[0.75, 3.21]	0.235
Quantifying sides or vertices				
Child age	0.04 (0.03)	1.04 (0.04)	[0.98, 1.11]	0.196
Parent education	0.32 (0.13)	1.37 (0.18)	[1.06, 1.79]	0.016
Child gender- F	0.07 (0.38)	1.07 (0.41)	[0.51, 2.26]	0.862
Puzzle- HA	0.41 (0.30)	1.51 (0.45)	[0.84, 2.7]	0.165
Order- TF	0.47 (0.38)	1.6 (0.62)	[0.75, 3.4]	0.221
Defining shapes				
Child age	0.03 (0.05)	1.03 (0.05)	[0.94, 1.13]	0.522
Parent education	0.24 (0.19)	1.27 (0.24)	[0.88, 1.85]	0.205
Child gender- F	0.72 (0.54)	2.05 (1.12)	[0.71, 5.96]	0.187
Puzzle- HA	0.00 (0.38)	1.00 (0.38)	[0.47, 2.1]	0.992
Order- TF	-0.07 (0.53)	0.94 (0.49)	[0.33, 2.63]	0.900

Note. IRR = incidence rate ratio. F = female. HA = highly alignable. TF = Typical puzzle first

Table 6
Negative Binomial Regressions Predicting Child Elaborative Shape Talk Utterances During Typical and Highly Alignable Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Child age	0.08 (0.05)	1.08 (0.05)	[0.98, 1.19]	0.105
Parent education	0.31 (0.19)	1.36 (0.26)	[0.93, 1.98]	0.108
Child gender- F	0.04 (0.55)	1.05 (0.57)	[0.36, 3.06]	0.935
Puzzle- HA	0.35 (0.35)	1.42 (0.50)	[0.72, 2.82]	0.312
Order- TF	0.78 (0.55)	2.17 (1.19)	[0.74, 6.34]	0.157

Note. IRR = incidence rate ratio. F = female. HA = highly alignable. TF = Typical puzzle first.

time spent such that older children engaged in more elaborative talk, IRR [95% CI] = 1.12 [1.04, 1.21]. Additionally, there was an effect of time spent, such that the longer dyads spent completing the puzzle, the more elaborative talk children used, IRR [95% CI] = 3.03 [1.80, 5.12]. Since elaborative shape talk was so infrequent for children, we did not analyze the data in terms of individual subtypes of elaborative shape talk.

3.3. Condition differences in parent and child shape talk based on shape arrangement

Table 7 reports descriptives for parent and child shape talk during the organized and unorganized versions of the Highly Alignable puzzle. To examine the effects of arrangement on parent and child shape talk, we ran negative binomial regression models predicting the frequency of shape talk utterances, accounting for child age, parent education, child gender, and the order of puzzles (i.e., whether dyads engaged with the Typical or Highly Alignable puzzle first).

3.3.1. Shape Labeling

In examining parents' shape labeling (see Table 8), measured as the total utterances where parents were only naming shapes or prompting children to do so, we found no effect of shape arrangement on parents' shape labeling, IRR [95% CI] = 0.01 [0.63, 1.63]. Parent education was again significantly associated with shape labeling; higher levels of education predicted more frequent parent shape labeling during the Highly Alignable puzzles, IRR [95% CI] = 1.22 [1.05, 1.43]. Further, there was also an effect of child gender, where parents engaged in less shape labeling with girls when engaged with the Highly Alignable puzzles, IRR [95% CI] = 0.56 [0.35, 0.91]. In examining children's shape labeling, we found no effect of puzzle arrangement, IRR [95% CI] = 1.06 [0.62, 1.83]. Of the covariates in the model, only child gender was significantly associated with shape labeling such that girls engaged in 59% less shape labeling than boys, IRR [95% CI] = 0.41 [0.23, 0.76].

3.3.2. Elaborative Shape Talk

In examining parents' elaborative shape talk (see Table 9), measured as the total utterances containing shape talk beyond labeling shapes, we found that the coefficient for shape arrangement approached significance, IRR [95% CI] = 0.58 [0.33, 1.03]. Parents engaged in 42% less elaborative shape talk while engaged with the Organized puzzle compared to parents completing the Unorganized puzzle. Of the covariates in the model, parent education was significantly associated with overall elaborative shape talk such that higher levels of education predicted more frequent parent elaborative shape talk.

As a follow up, we ran negative binomial regressions for individual types of elaborative shape talk. The main effect of shape arrangement appeared to be driven by a difference in parents' utterances about comparing and contrasting shapes, IRR [95% CI] = 0.34 [0.16, 0.72]. Parents engaged in 66% fewer utterances about comparing and contrasting during the Organized puzzle compared to the Unorganized puzzle when holding all other factors constant. There was not a significant effect of shape arrangement for any of the other subtypes of elaborative shape talk during the Highly Alignable puzzles.

In examining children's elaborative shape talk (see Table 10), we found that the effect of puzzle organization approached significance, IRR [95% CI] = 0.54 [0.21, 1.40], with children using 46% less elaborative talk during the Organized puzzle compared to the Unorganized puzzle. Similarly, the effects of child age, IRR [95% CI] = 1.08 [0.99, 1.17], and parent education, IRR [95% CI] = 1.39 [0.97, 2.00] were not significant but marginal; older children and children with more educated parents engaged in more frequent elaborative talk during the Highly Alignable puzzles. As previously noted, because children's elaborative talk was so infrequent, we did not analyze the individual subtypes of elaborative shape talk.

3.4. Child placement of puzzle pieces

Our analyses of parent and child shape talk indicated that the Highly Alignable puzzle, particularly the Unorganized arrangement, elicited more elaborative talk from parents. One potential explanation was that parents' talk might relate to children's performance in completing the puzzles, so we examined children's placement errors (see distribution of errors in Fig. 2). On average, children tended to make more overall errors on the Highly Alignable Puzzle, $M = 5.0$, $SD = 3.4$, than the Typical Puzzle, $M = 2.3$, $SD = 2.7$, $t(127) = -8.75$, $p < .001$, $d = 0.77$. We next looked more closely at whether children's errors tended to be within a shape category (i.e., placing a piece in an incorrect space from the same category: round, triangle, quadrilateral, or polygon with more than four sides). Thus, we compared the proportion of errors that were "within shape" category errors.[2] Children made a higher proportion of within shape category errors on the Highly Alignable puzzle, $M = 0.63$, $SD = 0.29$, than the Typical Puzzle, $M = 0.48$, $SD = 0.40$, $t(96) = -2.79$, $p = .006$, $d = 0.28$. Furthermore, to investigate the distribution of within and between category errors, we compared the proportion of errors that were within-category to 0.50. On the Typical puzzle children's likelihood of making within shape category errors did not significantly differ from 0.5, suggesting a similar distribution of within and between category errors, $t(96) = -0.37$, $p = .706$, $d = 0.04$. In contrast, on the Highly Alignable puzzles children made within category errors significantly more than 50% of the time, $t(96) = 4.38$, $p < .001$, $d = 0.44$. Thus, having more visually similar shapes may have increased the difficulty of completing the puzzle

[2] For analyses looking at proportion of within-shape type errors, to maintain a balanced within subject comparison and to ensure calculating the proportion of errors would not be overweighted by those with zero errors, we only analyzed data for children who made at least one error on both the Typical and Highly Alignable puzzles. This resulted in a subsample of 97 out of 128 children; 49 from the Highly Alignable Unorganized condition and 48 from the Highly Alignable Organized condition.

Table 7
Shape Talk During the Organized and Unorganized Highly Alignable Puzzles.

	Parents				Children			
	Organized		Unorganized		Organized		Unorganized	
Shape utterances	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
Shape labeling	4.19 (5.29)	0–20	4.12 (4.99)	0–19	2.21 (3.13)	0–13	2.22 (3.43)	0–15
Total elaborative	1.40 (1.86)	0–7	2.28 (3.71)	0–16	0.35 (0.93)	0–5	0.71 (1.93)	0–12
Describing shape features	0.29 (0.71)	0–3	0.23 (0.72)	0–4	0.11 (0.68)	0–5	0.09 (0.38)	0–2
Comparing shapes	0.29 (0.71)	0–3	0.75 (1.20)	0–4	0.05 (0.22)	0–1	0.14 (0.43)	0–2
Quantifying sides or vertices	0.71 (1.34)	0–6	1.09 (2.55)	0–11	0.16 (0.58)	0–3	0.46 (1.48)	0–9
Defining shapes	0.11 (0.37)	0–2	0.20 (0.59)	0–3	0.03 (0.18)	0–1	0.02 (0.12)	0–1

Table 8
Negative Binomial Regressions Predicting Shape Labeling Utterances During Organized and Unorganized Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Parents				
Child age	-0.01 (0.01)	0.99 (0.02)	[0.95, 1.03]	0.708
Parent education	0.20 (0.08)	1.22 (0.10)	[1.05, 1.43]	0.010
Child gender- female	-0.57 (0.24)	0.56 (0.14)	[0.35, 0.91]	0.018
Puzzle- organized	0.01 (0.24)	1.01 (0.25)	[0.63, 1.63]	0.957
Order- typical first	0.22 (0.24)	1.25 (0.30)	[0.78, 2.00]	0.356
Children				
Child age	-0.02 (0.02)	0.98 (0.02)	[0.93, 1.02]	0.309
Parent education	0.11 (0.09)	1.11 (0.10)	[0.93, 1.33]	0.252
Child gender- female	-0.88 (0.31)	0.41 (0.13)	[0.23, 0.76]	0.004
Puzzle- organized	0.06 (0.28)	1.06 (0.30)	[0.62, 1.83]	0.823
Order- typical first	0.04 (0.28)	1.04 (0.29)	[0.60, 1.80]	0.898

Note. IRR = incidence rate ratio.

Table 9
Negative Binomial Regressions Predicting Parent Elaborative Shape Talk During Organized and Unorganized Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Parent total elaborative talk				
Child age	0.02 (0.02)	1.02 (0.03)	[0.97, 1.07]	0.447
Parent education	0.28 (0.10)	1.32 (0.14)	[1.08, 1.63]	0.007
Child gender- female	-0.16 (0.29)	0.85 (0.25)	[0.48, 1.52]	0.594
Puzzle- organized	-0.55 (0.29)	0.58 (0.17)	[0.33, 1.03]	0.063
Order- typical first	0.29 (0.29)	1.34 (0.39)	[0.75, 2.37]	0.324
Describing shapes				
Child age	-0.03 (0.05)	0.97 (0.05)	[0.88, 1.06]	0.483
Parent education	0.40 (0.23)	1.50 (0.35)	[0.95, 2.36]	0.081
Child gender- female	-0.58 (0.56)	0.56 (0.31)	[0.19, 1.67]	0.300
Puzzle- organized	0.10 (0.56)	1.11 (0.62)	[0.37, 3.32]	0.852
Order- typical first	0.82 (0.58)	2.26 (1.32)	[0.72, 7.07]	0.161
Comparing shapes				
Child age	-0.02 (0.03)	0.98 (0.03)	[0.92, 1.05]	0.593
Parent education	0.15 (0.12)	1.17 (0.15)	[0.92, 1.49]	0.217
Child gender- female	-0.39 (0.38)	0.68 (0.26)	[0.32, 1.42]	0.305
Puzzle- organized	-1.09 (0.39)	0.34 (0.13)	[0.16, 0.72]	0.005
Order- typical first	0.75 (0.38)	2.11 (0.81)	[0.99, 4.48]	0.052
Quantifying sides or vertices				
Child age	0.03 (0.03)	1.03 (0.04)	[0.97, 1.10]	0.340
Parent education	0.32 (0.16)	1.37 (0.22)	[1.01, 1.87]	0.045
Child gender- female	-0.06 (0.43)	0.94 (0.40)	[0.41, 2.18]	0.893
Puzzle- organized	-0.49 (0.44)	0.61 (0.27)	[0.26, 1.44]	0.288
Order- typical first	0.08 (0.43)	1.08 (0.47)	[0.46, 2.53]	0.855
Defining shapes				
Child age	0.06 (0.05)	1.06 (0.06)	[0.95, 1.18]	0.282
Parent education	0.21 (0.21)	1.23 (0.26)	[0.82, 1.86]	0.314
Child gender- female	0.36 (0.58)	1.42 (0.83)	[0.46, 4.46]	0.540
Puzzle- organized	-0.56 (0.58)	0.57 (0.33)	[0.18, 1.79]	0.338
Order- typical first	-0.65 (0.59)	0.52 (0.31)	[0.17, 1.66]	0.271

Note. IRR = incidence rate ratio.

Table 10
Negative Binomial Regressions Predicting Child Elaborative Shape Talk During Organized and Unorganized Puzzles.

Variable	Coefficient (*SE*)	IRR (*SE*)	95% CI	*p*
Child age	0.08 (0.04)	1.08 (0.05)	[0.99, 1.17]	0.069
Parent education	0.33 (0.18)	1.39 (0.26)	[0.97, 2.00]	0.072
Child gender- female	-0.40 (0.53)	0.67 (0.35)	[0.24, 1.88]	0.205
Puzzle- organized	-0.61 (0.48)	0.54 (0.26)	[0.21, 1.40]	0.072
Order- typical first	0.89 (0.49)	2.44 (1.21)	[0.92, 6.46]	0.924

Note. IRR = incidence rate ratio.

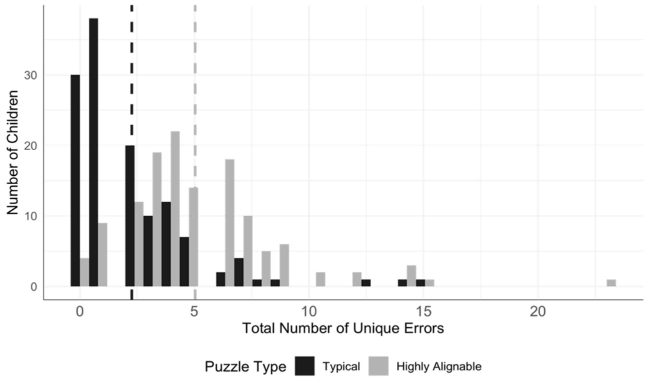

Fig. 2. A histogram of the number of unique errors children made on the Typical (black) and High-Alignment (lighter grey) puzzles. Dotted lines are placed at the mean number of errors made for each puzzle type.

and increased the likelihood of making within-shape category errors.

When comparing placement errors in the Highly Alignable puzzles, we did not find significant differences between the Organized and Unorganized versions. Children made a similar number of errors overall: Organized $M = 4.83$, $SD = 2.79$, Unorganized $M = 5.21$, $SD = 3.89$, $t(117.9) = -0.63$, $p = .532$, $d = 0.11$. Moreover, just over 60% of the errors tended to be within shape category errors in both versions of the Highly Alignable Puzzles (again only analyzing data from children who made at least one error: $n = 124$): Organized $n = 60$ (out of 62), $M = 0.63$, $SD = 0.30$, Unorganized $n = 64$ (out of 66), $M = 0.64$, $SD = 0.28$, $t(119.7) = -0.12$, $p = .899$, $d = 0.02$.

Our final exploratory analysis examined whether parents' elaborative talk correlated with children's placement errors. We found that parents' elaborative talk was not significantly correlated with the total number of children's placement errors during the Typical puzzle, $r(126) = -0.01$, $p = .908$, nor during the Highly Alignable puzzle, $r(125) = -0.07$, $p = .415$. Similarly, looking separately at the two versions of the Highly Alignable puzzle, we did not find significant relations between parent elaborative talk and children's placement errors during the Unorganized, $r(63) = -0.09$, $p = .500$, or Organized, $r(60) = -0.08$, $p = .558$, Highly Alignable puzzles.

4. Discussion

The current study examined how the alignability and arrangement of shapes in puzzles may influence parent and child talk about shapes during puzzle play. We hypothesized that modifying shape puzzles in a way that increased the alignability of shapes would prompt parents and children to use more elaborative talk in which they described and compared shape features. We found that parents, but not children, used more elaborative shape talk during the Highly Alignable puzzle than during the Typical puzzle. More specifically, parents used significantly more utterances that compared and contrasted shapes during the Highly Alignable puzzle. We also found that arranging similar shapes side-by-side decreased parents' and children's elaborative shape talk, but these effects of arrangement were much weaker than the effects of shape similarity, and not consistently significant. Further, parents and children focused on shape labeling more frequently, and used more shape word tokens across all shape utterances, during the Typical puzzle.

4.1. Influence of shape alignment on parent and child shape talk

There are several possible explanations for the greater amount of parent elaborative shape talk in the Highly Alignable puzzle. First, increased opportunities for discussing alignable shapes in the Highly Alignable puzzle may have supported parents' inclination to use comparisons as a teaching strategy with young children (Sandhofer, 2001; Valle & Callanan, 2006). That is, having shapes that were more similar may have drawn parents' attention to opportunities to discuss both the similarities and differences among shapes. As an example, below the parent initiates a discussion about the multiple triangles in the Highly Alignable puzzle:

Parent: Where is the triangle? There's three triangles, I think.

Child: Here. *Points to equilateral triangle.*

Parent: That's the usual triangle that we see, isn't it? Where does that triangle go?

Child: Is this another triangle? *Picks up scalene triangle and places piece next to equilateral triangle.*

Parent: That's a triangle, too. It's a different (*pause*) shape (*pause*) triangle. Because they all have three points. *Points to corners of scalene triangle.*

Another possibility was that parents may have used elaborative language in response to errors to scaffold children's puzzle completion by offering explanations as to why there was a mismatch or how to identify the correct match. Indeed, we did find that children made more placement errors on the Highly Alignable puzzle than on the Typical puzzle and these errors more often involved attempting to place a piece in a space within the same shape category (e.g., placing the isosceles triangle piece in the space for the right triangle). The following example shows how a parent engages in elaborative talk (utterances coded as comparing/contrasting are underlined) when a child is struggling to match the polygons with more than four sides:

Child: *Picks up pentagon and tries to place in hexagon space.*

Parent: *Hands child the hexagon and places octagon nearby.* Those are the same. Oh no. They're a little different.

Child: *Tries to place hexagon in pentagon space*.

Parent: Look. Just a little different. There's the stop sign right here. *Place octagon near octagon space.*

Child: *Tries to place pentagon in hexagon space.*

Parent: *Pointing to hexagon space,* This one has one additional side. *While tracing edges of pentagon space,* One, two, three, four, five sides. This one has… one, two, three, four, five, six sides.

Exploratory correlational analyses did not find a significant relation between parents' elaborative talk and children's placement errors. However, it is possible that some parents who used elaborative talk proactively – as in the first example - reduced placement errors whereas other parents used elaborative talk once their child made a placement error. Future microgenetic work examining parents' scaffolding during puzzles on a moment-to-moment basis may offer further insight into how and when parents use elaborative shape talk, and whether differences in these uses of elaborative shape talk are differentially beneficial to children's spatial thinking.

Our findings differ notably from another recent study by Verdine et al. (2019) which found that parents shape words and spatial talk did not differ when interacting with intermixed canonical and non-canonical shapes versus only canonical shapes, whereas 3-year-olds did use more shape words and spatial talk when interacting with the intermixed canonical and non-canonical shapes. There are at least two non-mutually exclusive explanations for the different pattern of results. First, the contexts and goals of the activities differed between studies. Verdine et al. asked parents to teach children about shapes using a set of shapes. Prompting parents to teach children about shapes might have led them to focus on labeling all the shapes regardless of the shape typicality or on asking children questions, thus increasing children's shape talk and spatial language and consequently the power to detect condition differences in children's talk. In contrast, in our study, where we asked parent-child dyads to complete a shape puzzle without any instruction to teach, it is possible that this context better reflects how parents would approach shape puzzles in naturalistic settings, resulting in parents offering verbal scaffolding when they deemed it was needed to support children's puzzle completion and autonomy rather than an opportunity to teach shapes. Second, the two studies also differed in how spatial language was measured. In our study, we focused specifically on talk about shapes, which may have been a more sensitive measure of condition differences than the broader measure of spatial language used by Verdine et al.

4.2. Influence of puzzle organization on parent and child shape talk

We also found evidence that the arrangement of highly alignable shapes within a puzzle frame may influence shape talk: parents used more (although not significant) elaborative talk when similar shapes were not side-by-side. Looking more closely at the different types of elaborative shape talk, we found that parents used significantly more comparison utterances when similar shapes were in different rows of the puzzle rather than next to each other. Children's elaborative talk was also marginally more frequent in the Unorganized puzzle condition, although given the rarity of children's elaborative talk, we did not examine the subtypes of elaborative talk individually.

These findings were contrary to our hypothesis that the side-by-side organization would facilitate more elaborative talk. Parents may have increased their elaborative shape language when visual alignment cues were less available (i.e., when similar shapes were in different rows) and/or decreased their elaborative shape language when visual alignment cues were more available (i.e., when similar shapes were side-by-side). Furthermore, it should be noted that children's placement errors, both in terms of frequency and type, did not significantly differ for the Highly Alignable Unorganized versus Organized puzzles. Considered together, these findings suggest that differences in parents' elaborative shape talk while engaged with the Organized and Unorganized puzzles may have been driven by their sensitivity to the visual alignment cues (or lack thereof) rather than their child's behavior. Thus, although prior work highlights the benefits of salient alignable differences for children's learning (Christie & Gentner, 2010; Strouse & Ganea, 2021), our findings, although speculative, suggest that parents may be sensitive to the benefit of alignment and compensate (via higher quality language) when that alignment is possible, but not as readily available.

4.3. Gender Differences in Parent and Child Shape Talk

Although gender was not a central factor in our present study, we included child gender in the model because research studies have found that it relates to both how parents engage with children in spatial activities and how children themselves talk about spatial concepts (e.g., Levine et al., 2012; Pruden & Levine, 2017). We found that both boys and parents of boys used more shape labels during the Highly Alignable puzzle compared to girls and parents of girls. However, there were not gender differences in the amounts of parent or child elaborative shape talk. It is unclear why we found a gender difference for shape labeling but not for elaborative shape talk. As discussed earlier, this may be due to the generally low levels of elaborative shape talk which may have limited our ability to detect small gender differences. Although the inconsistency in these gender differences makes them difficult to interpret, these findings generally align with previous literature that parents of preschool boys and boys themselves engage in more spatial talk (Pruden & Levine, 2017).

4.4. Implications, limitations, and future directions

Our results show that high alignment among shapes led to increased parent elaborative talk during puzzle play. We propose that enhancing parent and child elaborative shape talk through the design of spatial materials may be beneficial for supporting children's early spatial knowledge and conceptual understanding of shapes (National Research Council, 2009; van Hiele, 1999). Further, increasing the similarity among shapes also appears to increase the difficulty of puzzles by having more distractors from the correct placement. This increased level of challenge might serve as a desirable difficulty (e.g., Bjork & Bjork, 2020), such that greater challenge leads to increases in parent and child shape talk, which in turn may support children's conceptual understanding of shapes, and ultimately facilitate their spatial learning. An important open question, however, is whether increasing parent elaborative shape talk supports children's spatial learning. A limitation of the current study is that we only observed parent-child interactions shape talk during a brief, one-time interaction, and it was not feasible to assess children's learning. Thus, it will be important to investigate specifically how the quality of parent-child shape talk, and the role of activity design in eliciting this kind of talk, contributes to children's shape knowledge and geometric thinking in future work with longer-term interventions and child outcome measures that assess spatial thinking. It will also be helpful for future replications studies to include larger samples with more statistical power; due to experimenter error, our sample was slightly under-powered and this may have resulted in our failure to detect condition effects.

Another limitation of the current study is that our Highly Alignable puzzles utilized multiple strategies to increase alignment among shapes (i.e., multiple exemplars of triangles, less familiar quadrilaterals that could be not easily distinguished by labels, and visually similar polygons with more than four sides). Consequently, it is unclear whether all these strategies for increasing similarity were effective in increasing elaborative shape talk or difficulty in puzzle completion. Future studies that investigate how distinct types of alignment facilitate elaborative shape talk and spatial learning will be beneficial in determining which features of puzzles are important for enhancing parent-child elaborative shape talk during shape puzzles. Also, in our study we manipulated both the similarity of shapes and the typicality or familiarity of shapes, making it difficult to disentangle how these two dimensions may operate individually. Thus, it will also be interesting for future studies to examine how the familiarity of shapes, separate of the similarity of shapes, may offer affordances for families to engage in elaborative shape talk.

4.5. Conclusion

Although spatial language is important for children's early spatial development, there is variation in how much families engage in talk about spatial concepts (e.g., Pruden et al., 2011). Since spatial reasoning is important for math achievement (Geer et al., 2019; Gilligan et al., 2017; Gunderson et al., 2012; Verdine et al., 2017), and interventions targeting spatial knowledge have also led to increases in math knowledge (Cheng & Mix, 2014; Hawes et al., 2022; Hawes et al., 2017; Lowrie et al., 2019; Lowrie et al., 2017; Mix et al., 2020), facilitating high quality early spatial experiences has potential for supporting children's later mathematical success. In the present study, when playing with a shape puzzle like those typically available to families, parents and children engaged in very little shape talk beyond labeling shapes. However, our findings reveal the potential for shape puzzles to provide opportunities for deeper exploration of geometric and spatial concepts if puzzles include features - such as noncanonical, less familiar, and more visually similar shapes - that elicit rich shape talk.

Conflict of interest

We have no known conflicts of interests to disclose.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.cogdev.2022.101250.

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