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Associations between parents' number talk and management language with young children

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ABSTRACT

Evidence from a growing body of observational and experimental studies indicates that parent math talk is a key input supporting early mathematical thinking. Very little research, however, has been dedicated to understanding parenting or family correlates of math talk. In the present study, we examined relations between parents' number talk and their management language (i.e., the extent to which parents were controlling versus autonomy granting). Management language is predictive of children's executive functioning and, thereby, may also be relevant to math learning. During semi-structured play interactions with their young children ($n = 49$), parents who engaged in more number talk also used more autonomy supportive management language than did parents who engaged in less number talk, and this association was strongest once controlling for children's number talk. Our findings also provided preliminary evidence of variations in this association by parent education level: number talk and management language were more strongly associated for parents with less than a 4-year college degree than for those with a bachelor's degree or higher.

Introduction

A critical area of inquiry in developmental and learning science is focused on the environmental underpinnings of mathematics abilities in early childhood, which have proven to be robust predictors of later achievement (e.g., Claessens, Duncan, & Engel, 2009; Duncan et al., 2007). Evidence from a growing body of observational and experimental studies indicates that parent math talk is a key input supporting early mathematical thinking (e.g., Berkowitz et al., 2015; Casey et al., 2018; Gibson, Gunderson, & Levine, 2020). And, there appears to be considerable variability in how much math talk parents engage in with their young children (Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010). Very little research, however, has been dedicated to understanding parenting or family correlates of math talk; as a result, we know little about which parents are more or less likely to engage in math talk, or what types of parenting practices may accompany math talk. In the present study, we investigate one potential correlate of math talk: parents' behavior management language with their young children.

Our study follows theoretical and empirical work underscoring the ways parents often engage in clusters, or "profiles," of socialization strategies as a function of contextual and psychological factors, from cultural preferences to socioeconomic opportunity (or the lack thereof) to mental health (e.g., Bradley & Corwyn, 2004; Dearing & Taylor, 2007; Mayer, 1997; National Academies of Sciences, Engineering, and Medicine, 2016). We suspect that certain types of parent management language – namely the management language that has previously been shown to support children's executive function skills – may provide one such example of socialization practices that cluster together with math talk. Indeed, in assessments of what parents believe is important for their child's entry into kindergarten, analyses have indicated associations not only among academic skills (e.g., parents who report that literacy skills are important for kindergarten entry are also likely to endorse math skills as important) but also across developmental domains (e.g., higher ratings of academic skill importance are linked to higher ratings of the importance of social and EF skills; Barbarin et al., 2008; Piotrkowski, Botsko, & Matthew, 2001; Puccioni, 2015). Moreover, assessments of family math behaviors indicate that numerical and spatial support from parents of young school-age children are correlated both with one

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another as well as with the quality of the general home environment in the form of responsive interactions and materials for learning (Dearing et al., 2012). However, we do not know of any empirical work to date that has investigated whether numerical support (or any form of parent math support) is correlated with ways parents manage their children's behavior.

Why math talk and management language?

Our interest in management language as a potential correlate of math talk is driven by the fact that autonomy-granting styles of management language are positively correlated with young children's EF skills (Bindman, Hindman, Bowles, & Morrison, 2013), which are themselves closely entwined with math skills in early childhood (Bull & Lee, 2014; Clements et al., 2016). Beyond the cognitive interdependence of mathematical thinking and EF, correlated skills in these areas may arise from the types of learning and behavioral support parents provide. In other words, we suspect that parental support within young children's early learning environments may be one reason math and EF skills are correlated: parents who engage in the types of math talk that support math learning may also engage in forms of management talk that support EF. In fact, recent evidence from Son and Hur (2020) suggests that, when parent math talk occurs in the same context as high levels of EF-supportive talk with preschoolers (i.e., explaining activity steps and expectations), parent math talk is associated with higher child math skills over time (conversely, the authors found no associations between parent math talk, low levels of EF-supportive talk, and child skills). In the present study, we test the hypothesis that parent number talk will be correlated with behavioral management language during parents' play with their young children.

Several studies have demonstrated associations between EF skills, in particular working memory, and contemporaneous as well as later math achievement (for a review, see Cragg & Gilmore, 2014). For example, Welsh, Nix, Blair, Bierman, and Nelson (2010) found that growth in the EF domains of working memory and attention over a preschool year predicted growth in numeracy skills (as well as reading) during that same year. Similarly, there is evidence that early mathematics achievement is predictive of later EF skills (e.g., Watts et al., 2015). In a longitudinal study further unraveling contemporaneous and prospective relations between math and EF skills, Fuhs, Nesbit, Farran, and Dong (2014) demonstrate that during the preschool and kindergarten years, these associations are bidirectional: (1) EF and math skills at the beginning of preschool are strongly associated with one another; (2) early EF skills predict children's understandings of quantitative concepts and applied math problem skills at the end of preschool; and (3) while simultaneously controlling for autoregressive effects, math skills at the beginning of preschool predict EF skills at the end of preschool, and, in turn, children's EF skills at the end of preschool predict their math skills at the end of kindergarten.

Though correlational, these findings suggest a cascading relation between proficiencies in math and EF, for which children with high skill levels in both domains are most advantaged, longitudinally. What remains in question is whether certain environmental supports in children's early learning contexts might best trigger such positive cascades. We suspect that home environments during early childhood play a critical role in the individual differences observed in both math and EF prior to school entry. Moreover, beyond reciprocal connections between developing cognitive systems within children, we suspect that one reason math and EF skills are strongly correlated in early childhood is due to co-occurring developmental supports within the home environment; specifically, parents who support children's math skills may also be supporting children's EF skills, and vice versa.

Parenting, early math, and early EF

Early home learning experiences appear to be an important source of variability in children's early math and EF skill development (Anders et al., 2012; Dearing et al., 2012; Hackman, Gallop, Evans, & Farah, 2015; Kleemans, Peters, Segers, & Verhoeven, 2012; LeFevre et al., 2009; Rhoades, Greenberg, Lanza, & Blair, 2011; Sarsour et al., 2011). For early math, the extent to which adults talk about mathematical concepts (or don't) may be a critical driver of growth. Experimental evidence does, in fact, indicate that more teacher math talk – quantitative talk and spatial talk combined – during dialogic reading in preschool classrooms leads to improved child math language and numeracy skills (Purpura, Napoli, Wehrspann, & Gold, 2017; also see Gibson et al., 2020). Non-experimental work examining parents' interactions with their young children also appears consistent with this. For example, considerable variability in the extent to which parents use *number talk*, i.e., counting, labeling set sizes, quantity comparison, numeral identification, and arithmetic, with their young children has been evidenced during naturalistic observations (Levine et al., 2010; Susperreguy & Davis-Kean, 2016). And, several studies now indicate that variations in number talk are predictive of children's number knowledge during early childhood and prospectively into the early school years (Casey et al., 2018; Elliott, Braham, & Libertus, 2017; Gunderson & Levine, 2011; Levine et al., 2010; Ramani, Rowe, Eason, & Leech, 2015; Susperreguy & Davis-Kean, 2016). Levine et al. (2010), for example, found that the quantity of parent number talk between the time children were 14 to 30 months old predicted children's cardinal number knowledge (i.e., ability to label the set size of objects) at 46 months. Similarly, Susperreguy and Davis-Kean (2016) found that the amount of maternal number talk with 3- to 5-year-old children during mealtimes was associated with children's performance on a standardized math assessment one year later.

With regard to early EF, parenting again appears to be a key environmental factor helping to explain individual skill differences (e.g., Rhoades et al., 2011). The ways in which parents guide and manage their young children's behavior is thought to be one of the stronger contextual variables involved in emerging EF skills (Landry & Smith, 2010). Specifically, parental support of child autonomy in learning and self-regulation appears to be a robust positive predictor of EF during early childhood (Bernier, Carlson, & Whipple, 2010). Autonomy supportive parenting recognizes children's wants and needs and encourages children to take initiative therein; in turn, children are motivated to solve problems on their own (Grolnick & Pomerantz, 2009) and are likely to employ their EF skills when doing so (e.g., making a list of necessary steps; Bindman, Pomerantz, & Roisman, 2015).

In this line of evidence, there is also work indicating that the types of *management language* parents employ to help regulate their children's learning and behavior – ranging from more controlling language (statements and directives) to more autonomy granting (questions and choices) – are associated with EF skill growth (Bindman et al., 2013; Grolnick & Pomerantz, 2009). Researchers have previously identified parent management language as a daily scaffolding technique; parents use questions, statements, and actions to guide their children's behavior during mealtimes, learning activities, and other everyday occurrences and tasks (Kochanska, 1992; Kochanska, Kuczynski, & Maguire, 1989). And, the types of management language that parents use with their children has been found to be consequential; for instance, in a study by Kuczynski, Kochanska, Radke-Yarrow, and Girnius-Brown (1987), mothers' directive and commanding statements (e.g., "Put that down") were associated with more non-compliance from their children while suggestions (e.g., "Do you think that would fit better over here?") were associated with more child negotiations.

Regarding the relation between parent management language and children's EF more specifically, parenting that is more directive, or characterized by less autonomy granting, has been found to be negatively associated with children's EF skills at three years of age (Bindman et al., 2013). Consistent with this, Bernier et al. (2010) found that, above and beyond parental sensitivity and parents' attention to their children's mental states, autonomy support was a consistent predictor of EF between 18 and 26 months of age, even when adjusting for children's

general cognitive functioning. Interestingly, Kochanska and Aksan (2006) also found that children's self-regulation skills increased when their parents pointed out their ability to control *their own* behaviors. The different ways in which parents communicate to, and model for, children that their environment can be influenced and controlled may thus, in turn, impact how children's EF skills develop.

The potential moderating effects of socioeconomic status

There is considerable evidence that parenting and home environments vary as a function of family socioeconomics (SES) (e.g., Bradley, Corwyn, McAdoo, & García Coll, 2001; Hoff, Laursen, & Tardif, 2002). Higher SES parents have, over the last few decades, increasingly provided high levels of learning stimulation to their children (Reardon, 2011) and, in doing so, may demonstrate a greater propensity toward encouraging child autonomy than lower SES parents (Hoff et al., 2002). In their recent review, Kalil and Ryan (2020) point to the role of financial constraints, time constraints, stress exposure, and variations in child-rearing values as just a few of the many factors leading to differences in parenting between those in lower- and higher-SES homes.

Importantly, the consequences of these variations in parenting may not be limited to main effects on learning outcomes: SES can also moderate associations between parenting and children's learning outcomes, with evidence often pointing toward stronger associations between parenting and learning outcomes within lower SES environments than in higher SES environments (e.g., Casey, Dearing, Vasilyeva, Ganley, & Tine, 2011; Dearing, McCartney, & Taylor, 2009; Sarsour et al., 2011). These findings include evidence that parenting practices may be most strongly associated with children's EF skill growth in low SES contexts (Rochette and Bernier, 2014). One reason for this may be that positive parenting practices can buffer children from some negative consequences of socioeconomic disadvantage. Although less often examined, SES may also moderate the ways in which parenting behaviors cluster together (Bradley & Corwyn, 2004). To the extent that differences in constraints, stressors, and beliefs lead to variations in parenting within multiple domains, SES has the potential to affect the covariance of parenting behaviors. In the present study, we explore this possibility, examining whether SES – more specifically, parent education – moderates associations between parent number talk and management language.

The present study

In the present study, we examined correlations between two parenting behaviors – number talk and management language. Using data from a larger study on parent engagement in children's early math learning, we examined whether the frequency of parents' number talk was correlated with their use of management language during a semi-structured parent-child play session with toys chosen for their implicit affordances for math learning (i.e., a Duplo building blocks set and a kitchen set). Our hypothesis was that more frequent number talk from parents would be positively correlated with parent use of autonomy-supportive management language and negatively correlated with autonomy-limiting language.

For our second research question, we investigated whether associations between parent number talk and management language varied according to families' socioeconomic environments, using parent education level as a proxy for family socioeconomic status (SES). This analysis was driven by the potential for SES-related differences in family life (e.g., family finances, time constraints) to alter how, and how much, parenting supports for math learning and behavioral self-regulation covary. To the extent that parents with higher levels of education may be more highly engaged in number talk and demonstrate higher levels of autonomy support, we might expect stronger correlations between number talk and management language for parents with lower levels of education, simply as a matter of variability in the constructs. Of course, many parents in contexts of socioeconomic disadvantage invest highly in their children, despite experiencing challenging circumstances (e.g., Longo, McPherran-Lombardi, & Dearing, 2017; Mayer, 1997). And, several studies demonstrating early and persistent associations between math and EF skills have focused on lower SES samples of children (e.g., Blair & Razza, 2007; Fuhs et al., 2014; Welsh et al., 2010; Willoughby, Kupersmidt, & Voegler-Lee, 2012). We thus hypothesize here that correlations between positive parenting practices, namely those that support math learning and executive function skill growth, may be stronger for families of relatively lower SES than for those of relatively higher SES.

Method

Participants

Study participants included 49 parent-child pairs. The study took place at a large, Midwestern public event across five days. Parents were invited to participate in a survey about early learning and a semi-structured play observation with their child. In total, 60 parents agreed to participate in both the survey and video-taped play interactions. However, 11 recordings of play observations could not be analyzed due to protocol violations (e.g., a parent taking an extended phone call during the observation or the dyad discontinuing play almost immediately after beginning) or technical issues (e.g., microphone did not work). Thus, the final sample for the current study included 49 children (24 girls) and their parents (39 mothers, 10 fathers). On average, the children were approximately 3.5 years of age ($M = 3.55$, $SD = 0.88$), ranging from 2.0 to 4.83 years of age. The parent-reported racial identity of the participating children was 75.51% white, 8.16% Hispanic or Latino, 4.08% Asian American or Pacific Islander, 4.08% African American, and 8.16% multiracial. Parents were 25 to 53 years old ($M = 34.46$, $SD = 5.17$) with 85.71% identifying as white, 6.12% as Asian American, 4.08% as Hispanic or Latino, 2.04% as African American, and 2.04% as Native American. All but one family reported English as their primary home language for more details on the sample, see (Chan, Praus-Singh, & Mazzocco, 2020).

Procedure

Parents with preschool-age children attending the large public event were invited to participate in a 15-min semi-structured play session and complete a survey about early learning. After obtaining informed consent, a researcher escorted the parent and child to a semi-private (portioned space) play area and placed a bin containing a Duplo blocks set, a toy kitchen set, and a math storybook on the floor next to the parent and child (see Fig. 2). The researcher then instructed the parent and child to select an activity, asking, "Which of these activities would you like to play with first?" The parent and child were given five minutes to play with their chosen activity. After five minutes, the researcher prompted the parent and child to select one of the other activities from the bin within "two minutes." If the dyad did not switch activities within two minutes, they were reminded to select another activity from the bin. This procedure was repeated for the second and third activities. Upon completion of the final activity, the parent completed a survey containing family demographic questions and questions related to early learning.

In this study, we focus our analyses on the interactions that occurred during play with the kitchen set and Duplo set, but not with the math storybook. Consistent with other research that has found parents rarely go beyond the text to elaborate on math content when reading storybooks (e.g., Ramani et al., 2015), there was negligible variation in number talk during the storybook reading in the present study. Moreover, the more structured format of reading, compared with the less structured play that occurred with the Duplos and kitchen set, also greatly limited variations in management language during storybook

reading. It was also the case that the storybook was the last activity chosen by all families, and some families decided to end their interactions before reading the storybook. The kitchen set and Duplo set, on the other hand, provided multiple opportunities for parents to both talk about number and manage their children's behavior in an unscripted fashion. Indeed, these two activities provided opportunities for speaking about quantity (i.e., they each have multiple pieces that can be grouped into sets, counted, combined and separated, etc.) but did not explicitly require number talk to play with them. They also allowed ample room for parents to direct and negotiate children's behaviors, given the multiple activity pieces and ways to arrange them. All families in our final sample interacted with both the kitchen and Duplo blocks sets.

The kitchen set included 4 cups and 4 plates, a wooden toy knife, a cutting board, and wooden food items (i.e., bread, carrot, cucumber, apple, tomato, pepper, and watermelon) that could be divided into slices and reconnected by hook and loop fasteners. Two Duplo blocks sets were used during the observations. About half of the dyads received a Duplo set containing 52 pieces of varying sizes, shapes, and colors. The other half received a Dulpo set that contained six additional pieces. Three of these pieces were labeled with numerals (1–3) and the other three had a decal depicting the corresponding numerosity (1 radio, 2 mice, 3 apples). Although not the focus of the present study, the two different Duplo sets were used to examine whether the Duplo pieces with numeric information would elicit more number talk than those without numeric information; in the present study, we control for this possibility while focusing on average number talk across the two activities.

All parent-child observations were video-recorded. Recordings were transcribed by a professional transcription service and verified by a team of trained researchers. In addition to audio, descriptions of the parents' and children's actions were included within the transcription. The transcripts were coded for parent management language and instances of parent number talk by five coders. All coding was completed at the utterance level, with an utterance demarcated by either a sentence-ending punctuation mark in the transcript or a prolonged pause within a speaking turn.

Measures

Family demographics

Within the surveys administered after the parent-child interactions, parents reported their family demographics, including child age, child race/ethnicity, parent race/ethnicity, and parent education. For education, the participating parent reported their own highest level of education completed. In the present study, we treated this indicator as quantitative scores (from 1 to 7) based on response options that ranged from "did not complete high school" (1) to "graduate or professional degree" (7). On average, the sample was highly educated: 8 parents (16%) had a year of college or less, 5 (10%) had an associate's degree or equivalent, 19 (39%) had a bachelor's degree, and 17 (35%) had at least some graduate-level training (of which 13 had a graduate degree). In the present study, we used parent education as a proxy for SES. This decision was driven, in part, by data limitations (i.e., our parent demographic survey did not require parents to report their income) but research suggests that parent education is a commonly used measure of social class (Aud et al., 2012; Lien, Friestad, & Klepp, 2001) and is less intrusive to families than measures of income (Aud et al., 2012).

Parent number talk

Based on previous research (e.g., Ramani et al., 2015), we devised a number talk coding scheme in which parent and child utterances received a number talk code if the utterance included counting, cardinal values, correspondence, magnitude comparisons, fractions, numeral identification, arithmetic, prompts (e.g., "how many?"), or other clearly quantitative statements that did not fit into any other categories but elicited child performance of a numeracy skill. Number talk coding was completed using a two-step process. First, utterances were coded as to whether or not they contained number talk. Then, each number talk utterance was coded into the specific categories of number talk listed above. Occasionally, counting sequences spanned across multiple utterances; when this occurred, only the final utterance in the number sequence received a code. An utterance could receive more than one number talk code if it met criteria for more than one number talk category. To establish interrater reliability, coders first independently applied the number talk codes to the Duplo set activity portion of 13 transcripts (26.5% of the total sample). Where codes differed, consensus was used to determine the final code. Reliability was good, with Cohen's Kappa of 0.89 for parent utterances. Within the kitchen set activity portion of the transcripts, coders independently coded 12 transcripts (24% of the total sample). Again, reliability was good, with Cohen's Kappa of 0.90 for parent utterances.

For our analyses, we collapsed the utterance frequency data across sub-categories of number talk, hoping to minimize problems with low base rates within sub-categories and to increase parsimony in our analytic models. Specifically, we created two variables representing (1) the total number of parent utterances and (2) the total number of child utterances that received at least one number talk code during the Duplo set and kitchen set activities. For parents, the average frequency of number utterances was 3.45 ($SD = 4.65$) and 3.06 ($SD = 3.82$) during play with the Duplos set and Kitchen set, respectively. For children, the average frequency of number utterances was 1.78 ($SD = 2.39$) and 2.28 ($SD = 3.20$).

From these totals, we computed two proportion variables: (1) the proportion of total parent utterances that were coded as number talk and (2) the proportion of total child utterances that were coded as number talk. As noted below regarding the parent management language variables, this proportion approach helped to account for differences in observation length and overall frequency of parent talk. Underscoring the potential usefulness of child number talk as a covariate (i.e., to help control for children's contributions to the correlations between parent number talk and management language), the proportion variables for child and parent number talk were strongly and positively correlated ($r = 0.66$, $p < .001$).

Parent management language

We coded parent management language using a coding scheme adapted from Bindman et al. (2013). A parent utterance was categorized as management language if it included a statement, direction, or question that had a direct implication for the child's actions or behavior immediately following the utterance (see Table A1 for examples). Only management language that was directed toward the child and aimed to further the child's participation or progress within the study activities was coded. Each management utterance was further coded into one of six categories.

The categories were designed to capture a continuum of parental autonomy support, ranging from full control over children's actions (explicit direction) to granting children full autonomy (transfer statement). The six management language codes included: (1) Explicit Direction – a statement that includes a direct command to the child (e.g., "Put that piece there"); (2) Qualified Direction – a statement in which the parent gives the child a direct command, but qualifies the command with a final question (e.g., "Put it away now, okay?"); (3) Ambiguous Suggestion – a statement in which it is unclear whether the parent is providing the child with a choice in their behavior (e.g., "Can you get the book now?"); (4) Choice Question – a statement where the parent provides the child with two or more alternative behaviors (e.g., "Should we put them back together, or should we keep them like that?"); (5) Single Suggestion – a comment that gives the child a clear behavioral suggestion and a choice whether to accept that suggestion (e.g., "You could put

it like this"); and (6) Transfer Statement – an utterance in which the parent cedes control of the situation to the child, providing the child with full autonomy over his or her behavior (e.g., "What should we make?"). A variable was created for each management language category, representing the total number of occurrences of the category within each observation. To establish interrater reliability, two researchers coded the same 12 transcripts (21.4%) independently and calculated the Spearman-Brown correlation between the codes. The Spearman-Brown correlation was $r = 0.96$ across all six management language categories, indicating excellent interrater reliability.

In the original scale development work, Bindman et al. (2013) used an exploratory factor analysis with Maximum Likelihood Extraction and Geomin rotation to consolidate the raw data from the six domains of management language into two succinct factors. This analysis yielded two factors: Explicit Directives and Qualified Directions loaded onto the first factor, and Ambiguous Suggestions, Single Suggestions, Choice Questions, and Transfer Statements loaded onto the second factor. In our data, we replicated this factor structure.

We created two composites (sum scores): directive language (factor 1) and autonomy supportive language (factor 2). The factor loadings, means and standard deviations, and correlations among sub-domains are reported in Table 1. It should be noted, however, that the correlations among sub-domains partly reflect the overall amount of management language (and the overall amount of parent talk) in which parents engaged; for example, while explicit directives were positively associated with both ambiguous suggestions and transfer statements for the raw frequency scores (see Table 1), they were strongly negatively correlated if we adjusted for total amount of management language ($r = -0.58$ for explicit directives and ambiguous suggestions, and $r = -0.59$ for explicit directives and transfer statements). Thus, in our primary analyses, we used proportion scores for directive and autonomy supportive language, dividing the raw frequencies by total parent talk. In addition, directive language scores were statistically controlled when estimating associations between autonomy supportive language and number talk, and vice versa. [Note that the proportion scores were positively correlated ($r = 0.27$, $p = .06$), albeit not as strongly as were the total frequency scores for these two factors ($r = 0.49$, $p < .001$), given that total talk inflated the latter.]

Statistical analyses

For our primary analyses, we did not make assumptions as to the direction of association between parents' management language and number talk, but focused instead on patterns of covariation between the constructs. To do this, we estimated two sets of partial correlations – bivariate correlations for which additional variables are controlled in a manner identical to the inclusion of covariates in multivariate regression modeling – between management language and number talk. In the first set, partial correlations were estimated between parent number talk, autonomy supportive language, directive language, and education. Specifically, partial correlations were estimated for each variable pair (i.e., six correlations) while simultaneously controlling for the remaining two variables (e.g., the association between parent number talk and parent autonomy support was estimated while controlling for parent directive language and parent education). In the second set of partial correlations, we also controlled for child number talk (e.g., the association between parent number talk and parent autonomy support was estimated while controlling for parent directive language, parent education, and child number talk).

Following the partial correlations, we examined interactions between parent management language and parent education, allowing the associations between management language and number talk to vary by parent education. To do this, we estimated ordinary least-squares regression models with the management language composites (parent directive and autonomy supportive language) specified as outcome variables and the following specified as predictors: number talk, parent education, and the number talk by parent education interaction. For the regression models, it is worth underscoring the fact that our decision to specify management language as the outcome variable was not driven by a directional hypothesis; thus, we also estimated an OLS model with parent number talk specified as the outcome, with the two management language variables, parent education, and the two corresponding interactions specified as predictors.

Table 1
Descriptive statistics for parent talk study variables (N = 49).

	Mean	SD	Range
Total Parent Utterances	215.94	84.54	65–499
Management Language Domains			
Explicit directives	15.56	12.97	1.0–57.0
Qualified directives	0.82	1.29	0.0–6.0
Ambiguous suggestions	16.45	8.49	3.0–34.0
Choice questions	1.31	1.5	0.0–7.0
Single suggestions	3.90	3.29	0.0–11.0
Transfer statements	6.20	4.70	0.0–19.0
Management language composites[a]			
Directive language	7.92%	6.42%	0.78–27.36%
Autonomy supportive language	13.43%	4.97%	3.22–26.86%
Number talk proportional to total talk	2.91%	2.52%	0.00–12.05%

[a] *Note*. The composite management language variables and the "parent number talk proportional to total talk" variable were proportions relative to all parent utterances during the interactions.

Results

Descriptive statistics and preliminary analyses

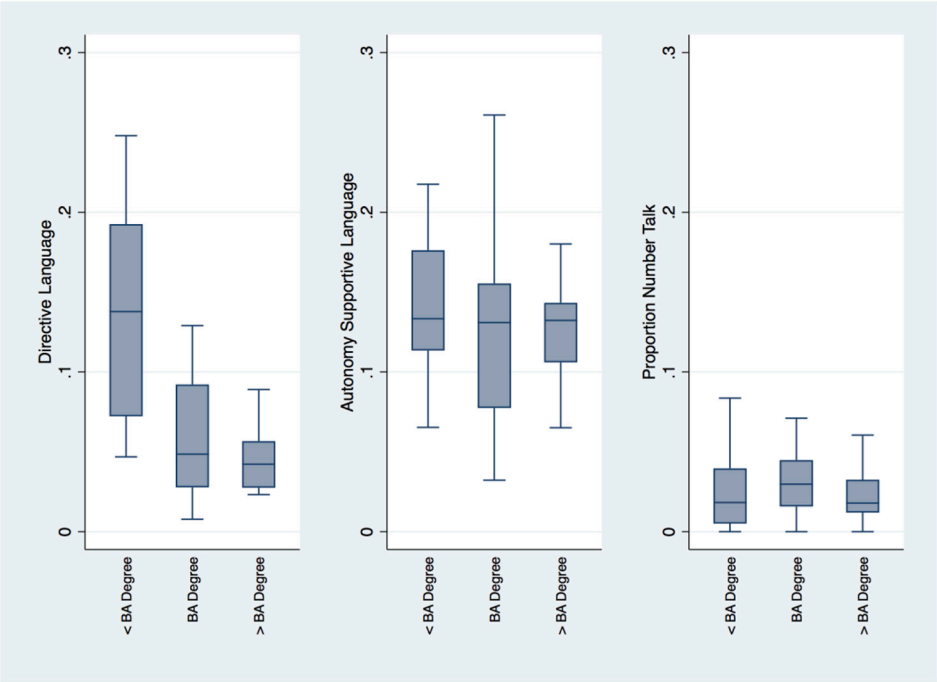
In Table 1, we present descriptive statistics for total parent talk, the proportion of parent talk that was number talk, total management language (by domain), and proportion of parent talk that was directive or autonomy supportive. In terms of percentage of total parent utterances, both number talk and management language were, on average, relatively rare; across the six subcategories of management language, ambiguous suggestions and explicit directives were the most commonly observed. Within the two activities, there was somewhat more number talk during play with the Duplos and somewhat more management language during play with the kitchen set, but these differences were not statistically significant (i.e., 47.17% of number talk utterances, 56.77% of autonomy supportive language, and 58.44% of directive language occurred during play with the kitchen set).

Given our interest in the potential moderating role of parent education, Fig. 1 provides box plots of the distribution of directive, autonomy supportive, and number talk proportion scores for parents whose highest degree was either: less than a Bachelor's degree ($n = 13$), a Bachelor's degree ($n = 24$), or a graduate degree ($n = 13$). Of note, for all three variables, the narrowest distributions were evident for the most educated parents.

Partial correlations: associations between number talk and management language

In Table 2, we provide partial correlations among the study variables. Partial correlations above the diagonal were adjusted for all other variables in the table while partial correlations below the diagonal were adjusted for all variables listed in the table as well as child number talk. Considering the partial correlations prior to adjustment for child number talk (i.e., above the diagonal), parent number talk and both domains of management language were significantly related to one another. Higher rates of number talk were associated with lower rates of directive language and higher rates of autonomy supportive language from parents, holding constant the fact that these two domains of management language were positively correlated with one another. In addition, directive language was fairly strongly related to parent education, such

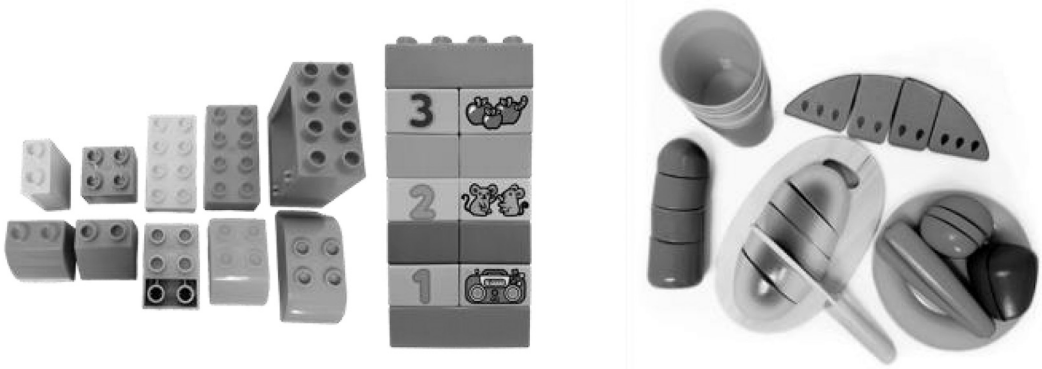
Distribution of Scores by Parent Education



Note. The boxplots display the median as well as the 25th and 75th percentiles; the whiskers of the plot display values at 1.5 times the interquartile range below the 25th percentile and above the 75th percentile.

Fig. 1. Distribution of scores by parent education.
Note. The boxplots display the median as well as the 25th and 75th percentiles; the whiskers of the plot display values at 1.5 times the interquartile range below the 25th percentile and above the 75th percentile.

Duplo Blocks Sets and Kitchen Set



Note. On the far left is the standard Duplo blocks set (without numerals) and, in the middle, is the Duplo blocks set with numerals.

Fig. 2. *Duplo Blocks Sets and Kitchen Set.*
Note. On the far left is the standard Duplo blocks set (without numerals) and, in the middle, is the Duplo blocks set with numerals.

that parents with relatively lower education levels used more directive language than did those with higher education.

After controlling for child number talk in these partial correlations (i.e., correlations below the diagonal in Table 2), changes in the findings for associations between parent number talk and management language were noteworthy. On one hand, the association between parent number talk and directive language was smaller and no longer statistically significant ($r = -0.23$, $p = .13$) once controlling for child number talk. However, the association between parent number talk and autonomy supportive language was larger and remained significant once controlling for child number talk ($r = 0.46$, $p = .001$). Both of these changes in partial correlations prior to and after including child number talk were statistically significant (Wald tests of "seemingly unrelated" estimates were $\chi^2 = 6.61$, $p = .04$ and $\chi^2 = 7.38$, $p = .03$, respectively).

Table 2
Partial correlations for parent number talk and management language (N = 49).

	Parent number talk	Directive language	Autonomy supportive language	Parent education
Parent number talk	-	−0.35*	0.32*	−0.28
Directive language	−0.23	-	0.33*	−0.55***
Autonomy supportive	0.46**	0.29	–	0.11
Parent education	−0.07	−0.55***	0.02	–

Note. Partial correlations above the diagonal were adjusted for all other variables in the table; partial correlations below the diagonal are adjusted for all other variables in the table as well as child number talk.
*$p < .05$ **$p < .01$ ***$p < .001$.

Regression models: moderating effects of parent education

In the first two columns of Table 3, we provide a summary of findings from the regression models in which we examined whether relations between parent management language and number talk varied by parents' levels of educational attainment. For both management language domains, the interaction was statistically significant. The direction of these interactions indicated, in both cases, that evident associations between parent number talk and management language were strongest for parents in the sample with relatively lower levels of education. The region of significance for this interaction indicated that more directive language was significantly associated with less number talk for parents with less than a bachelor's degree (i.e., for these 13 parents, $b = -1.20$, $p = .001$), but this association was null for those with a bachelor's degree or higher (i.e., for these 36 parents, $b = -0.08$, $p = .78$). Similarly, for parents with less than a bachelor's degree, more autonomy supportive language was associated with more number talk ($b = 0.95$, $p < .001$) but this association was null for parents with a bachelor's degree or higher ($b = 0.21$, $p = .50$). Note that these interactions were replicated in the model for which parent number talk was specified as the outcome (last column of Table 3) and both management language variables were allowed to vary (simultaneously) by parent education.

Table 3
Summary of regression models estimating the moderating effects of parent education (N = 49).

	Directive language	Autonomy supportive language	Parent number talk
Parent number talk	−2.58***	1.87**	
	(0.63)	(0.57)	
Parent education	−0.03***	0.01	
	(0.01)	(0.01)	
Parent number talk x Parent education	0.43**	−0.28*	
	(0.12)	(0.13)	
Directive Language			−0.58**
			(0.20)
Autonomy supportive language			0.74*
			(0.29)
Parent education			0.01
			(0.01)
Directive language x parent education			0.11*
			(0.05)
Autonomy supportive language x parent education			−0.13*
			(0.06)

Note. Directive language was included as a covariate when predicting autonomy support, and vice versa (i.e., similar to those in Table 2, effect sizes (*r*) ranged from 0.29 to 0.38).
*$p < .05$ **$p < .01$ ***$p < .001$.

Follow-up analyses

Based on the results of our primary analyses, we conducted two sets of follow-up analyses. First, we more closely examined the variability in management language to ensure that the effect sizes we estimated for less educated parents applied to a reasonable portion of our sample. Second, we qualitatively examined the parent talk data to determine the level of overlap between utterances that simultaneously received a number talk code and a management language code. The purpose of this second follow-up was to determine whether number talk and management language were correlated because they were one in the same (e.g., are the number talk utterances among less educated parents also transfer statements?) or because parents who did more number talk also did more or less of certain types of management language, despite the utterances in the two domains being distinct.

Regarding the first follow-up analyses, it was evident that, although less educated parents' mean levels of directive language were higher than those of highly educated parents, there was also considerable variability among less educated parents. The number of explicit directive statements, for example, ranged from 6 to 66 among the 13 parents with less than a bachelor's degree; as a comparison, this ranged from 2 to 62 for highly educated parents. And, about half of the less educated parents (6) displayed explicit directive levels near or below (19 or less) the sample mean. Similarly, at the other end of the management language continuum, the range of transfer statements among parents with less than a bachelor's degree was 0 to 14 (these values ranged from 0 to 19 for more highly educated parents), with about half (6) of these parents near or above the sample mean (i.e., 6 or higher).

For the second follow-up analyses, we coded each instance of parent number talk for (1) whether the number talk utterance also received a management language code and, if so, (2) which management language code the utterance received. This analysis indicated little overlap in parent utterances in these domains. In total, less than 20% (17.5%) of parent number talk utterances were also coded as management language. Of those utterances that did receive both a number talk and management language code, most (10.6% of number talk utterances) were ambiguous suggestions (in turn, 4.5% were explicit directives, 1.4% were single suggestions, and less than 1% were coded as transfer statements, choice questions, or qualified directives). On the other hand, 21.4% of parent non-number talk was coded as management language. Comparing the proportions of number and non-number talk that were coded as management language were not significantly different ($\chi^2(1) = 2.00$, $p = .16$).

Robustness checks

In addition to our primary models, we examined the robustness of our findings to the inclusion of the following additional covariates (entered one at a time for reasons of parsimony) in both the partial correlation and regression models: parent age, parent gender, child age (in months), child gender, child race, type of Duplo set (with or without number stimuli), and order of activity (kitchen set first or Duplo set first). Our results remained substantively identical (in direction, effect size, and statistical significance) with or without these additional covariates. And, no additional covariates reached statistically significant levels in their associations with parent number talk or management language, with the exception of parent age and child age for directive language (i.e., younger parents used more directive language, $r = -0.32$, $p = .03$, and parents used more directive language with younger children, $r = -0.35$, $p = .02$). For our regression models, we also included child number talk as a covariate (as we did with the partial correlation models); results from these models were substantively identical to those without the additional control (in terms of statistical significance, effect size, and direction of effect).

We also re-specified our partial correlation and regression models using alternative versions of the management language variables.

Specifically, rather than using the directive and autonomy supportive composites, we re-estimated our models using: (1) a single omnibus indicator in which we summed autonomy support and directive language (reverse coded) and (2) the two individual management language domains representing opposite ends of the directive-autonomy support continuum (i.e., explicit directives and transfer statements). Results from these two approaches (in both main effects and interactions) were entirely consistent with those we presented here in terms of expected direction and statistical significance.

We also checked the robustness of our results using the total amount of parent number utterances, while controlling for total parent utterances (number and non-number), rather than computing a proportion of total talk that was number talk. This robustness check helped ensure that the proportion approach was not inflating the influence of extreme values (e.g., parents with very little talk but for whom most of that talk was number talk). All of our significant associations and interactions evident when using proportions were also evident (and very similar in effect size) when using total parent number talk adjusted for total talk. Finally, we also examined the associations of interest within each activity separately (i.e., kitchen set versus Duplo set), and the direction and strength of the associations between number talk and management language did not significantly differ across the activities.

Discussion

In the present study, we examined correlations between parent number talk and management language, the former having demonstrated predictive relations with math skills and the latter having demonstrated predictive relations with EF skills. We also explored the possibility that parent number talk and management language may be most strongly associated for relatively less educated parents. While we have focused exclusively on parent behaviors in these domains (and did not study child skills), our results may provide a first step toward understanding whether correlated parenting supports help explain, in part, the strong correlation between math and EF that emerges in early childhood. In addition, our results could help inform parenting interventions; given the associations we detected between parental support of math and executive functioning, there may be opportunities for dovetailing these two support domains for children at risk.

Children's math and EF skills are correlated beginning in early childhood (e.g., Cragg & Gilmore, 2014; Fuhs et al., 2014; Watts et al., 2015; Welsh et al., 2010), with potential bidirectional influences unfolding over time. We suspect that one reason for early emerging correlations between children's math and EF skills may be early caregiving; the critical cognitive (and underlying neurological) connections between these two constructs notwithstanding, our results indicate that caregiving behaviors that support children's math and those that support children's EF co-vary. Our findings are consistent with the research demonstrating that parenting behaviors that promote learning appear to cluster together (e.g., Dearing & Taylor, 2007; Mayer, 1997), although we are unaware of any prior research examining this relation for parental support of early math and EF skills.

Number talk and management language

We found that parent number talk was related to parent management language, and most robustly so for autonomy supportive language, once controlling for potential child evocative effects. Prior to controlling for child number talk, parent use of directive language and autonomy supportive language were both associated with parent number talk, although in opposite directions. Parents who used more directive management language engaged in less number talk than other parents, and those who used more autonomy supportive language engaged in more number talk. When interpreting these findings, it is critical to note that directive language involves parental control over interactions with their children; these are statements in which the child was not offered choices or given the opportunity to make decisions about the direction of play. Conversely, autonomy supportive language involves parents transferring power to the child during the interaction by offering choices, suggestions, and using questions that allowed children to determine the focus of their play together.

It is believed that more controlling behavior management limits children's opportunities to engage in independent problem solving and, as a result, limits children's opportunities to improve their cognitive self-regulation (Merz et al., 2016; Ryan & Deci, 2000). In fact, more controlling forms of behavioral management have been found to negatively predict children's executive functioning as early as three years of age (Bernier et al., 2010; Bindman et al., 2013; Merz et al., 2016). And, consistent with developmental theory on the benefits of autonomy support for promoting self-regulation, this form of parenting is predictive of better child executive functioning skills (e.g., Bernier et al., 2010; Bindman et al., 2013; Merz et al., 2016).

Importantly, in the present study, although associations between directive language and parent number talk were significantly reduced in size when controlling for child number talk, the association between autonomy supportive language and parent number talk significantly *increased* in size when controlling for this child variable. We included children's number talk as a covariate to help control for the possibility that some portion of the correlations between parent number talk and management language may be a function of the child's contribution to the interactions. On the one hand, our findings were consistent with the assumption that the negative association between parent number talk and directive language may have been due, at least in part, to some children evoking lower levels of parent number talk and higher levels of directive language than other children. Yet controlling for child number talk, in fact, strengthened the association between parent number talk and autonomy support. We believe this finding provides some evidence that parent number talk and autonomy support may co-occur for reasons above and beyond children's contributions to parent-child interactions. However, we cannot rule out additional sources of child evocative effects beyond their number talk; a fact that we discuss in greater depth within the context of our study limitations.

Moderating effects of parent education: preliminary evidence

In addition to the main effect associations we detected in partial correlations, we also found preliminary evidence that associations between parent number talk and management language – both directive and autonomy supportive language – may be strongest for less educated parents. One explanation for this may relate to variations in how controlling the lower versus higher educated parents were during interactions with their children. Regardless of frequency of number talk, more educated parents used fewer directives to manage their children's play than did less educated parents. Although this result is consistent with the literature (e.g., Hoff et al., 2002), other studies have not detected relations between SES and controlling language (Bindman et al., 2013), perhaps as a function of the type of parent-child interaction being studied. In the Bindman et al. (2013) study, for example, parents and children were given a goal-directed task: planning a birthday party. It may be that introducing a goal is more likely to evoke higher levels of control among more educated parents than was evident in our study, in which parents and children were simply instructed to play together.

However, it was not the case that more educated parents offered uniformly high frequencies of number talk. In fact, number talk was rare for all parents, and education level did not significantly predict which parents used more number talk (this correlation was negative, and close to zero once we controlled for child number talk). This finding is consistent with other work investigating relations between number talk with young children and both parent education and family income (e.g., Casey et al., 2018). It may be that both relatively lower and higher educated parents face obstacles, such as math anxiety, to talking about early math concepts with their children (Maloney, Ramirez, Gunderson,

Levine, & Beilock, 2015).

Given these interaction effects, another question our findings raise is whether correlated environmental supports could be particularly critical to developing cognitive capacities in early math and EF for children in lower SES families. However, the present study's focus on parenting behaviors is just a first step toward understanding the role of early environment in links between EF and math; the next step requires attention to child outcomes in both math and EF domains. Moreover, interpreting the interaction between management language and parent education deserves a word of caution related to our overall sample size and the limited number of less educated parents who we observed interacting with their children.

Study limitations

While the present study's focus on correlated supports in children's early caregiving environments is novel, it is critical to recognize that the study sample was, on average, relatively well educated and predominantly white. Even the less educated parents in our sample had completed high school, if not two years of college education. This may be one reason we see a range of number talk frequencies and autonomy granting management strategies among the less educated parents; it is not clear that this level of variation would be evident among parents with very low levels of educational attainment. In addition, the decision to use parent education as a proxy for SES was driven by the data limitations of this study; had data on other dimensions of SES been available, we may have obtained different results.

We also note that we have examined only one domain of support related to early math learning and one domain related to executive functioning, and these have been observed within a single semi-structured play session. This work could be extended to include a broader range of parenting support behaviors, for both math (e.g., spatial learning support) and EF (e.g., sensitivity), and our work could be extended by attention to a broader range of settings and activities. Moreover, it would be valuable for future work to examine other forms of learning support (in domains that are less closely related to EF, for example) as a means of determining whether these associations are unique to number talk (or math talk) or are more general to high-quality learning support. That said, we chose to focus on two types of support (parent math talk and management language) that have been robustly predictive of children's growth in math and EF, and our focus on direct observations of talk provided a rich, targeted, and nuanced analysis compared with parent self-reports or more domain-general observational assessments. Future work examining whether these links are domain-general associations between multiple forms of math and EF supports or domain-specific (e.g., limited to number talk and management language) would be valuable.

The relatively small sample in the present study was also a concern. Other than zero-order correlations, our sample was too small to reach a statistical power (i.e., 1-β) of 0.80 for correlations of the magnitude we observed. As a result, valid concerns include both a high likelihood of Type II errors (incorrectly failing to reject the null) and the potential for the magnitude of detected effects to be exaggerated (Button et al., 2013). Another limitation of the current study related to sample size was that we could not include a range of covariates when investigating the correlations of interest without exacerbating power concerns. In particular, while we were able to control for children's number talk and child age (which may serve as a proxy for child self-regulatory capacities), we did not directly control for the child behavioral precursors or responses to variations in management language within the interactions (for examples, see Table A1). This was because, although the majority of parent management utterances appeared to be spontaneous, the analytic complexity of capturing behavioral precursors and subsequent responses was considerable. Because qualitatively distinct types of child behaviors occurred prior to (and in response to) each management language domain, and vice versa, similar child behaviors occurred prior to (and in response to) parents' use of different management language types. Controlling for these variations would thus have required an unreasonable number of additional covariates in our statistical models given our sample size. As some indication of this variability and to inform future work in this area, we include (in the appendix) examples of the types of child behaviors that elicited directives and autonomy support.

Finally, we were not able to address why, precisely, correlations between number talk and management language arose within families, nor were we able to investigate whether these correlated parent talk domains predicted variability in children's numerical or EF skills. Nonetheless, this work does provide a first step in documenting co-occurring learning supports for math and EF. Understanding both the precursors and consequences of correlated parent number talk and management language would be a valuable next step.

Finally, although not necessarily a study limitation, we did find it surprising that the two domains of management language were positively correlated with one another, albeit not always significantly so. One reason for this positive association could be that any form of management talk is somewhat dependent on child behavior; more active or dysregulated children, for example, may receive more overall management talk from their parents, both directive and autonomy supportive, than less active or more self-regulated children.

Implications for practice

With the study limitations notwithstanding, we believe there are important applied implications of this work, namely in the area of supporting positive parenting practices. Critical elements of effective parenting programs and interventions have recently been identified (National Academies of Sciences, Engineering, and Medicine, 2016). One evident trend is the success of programs that partner with parents to help improve parental support of *both* young children's academic skills and their behavior management (i.e., self-regulation). For example, the Let's Play in Tandem and REDI-P interventions (e.g., Bierman, Welsh, Heinrichs, Nix, & Mathis, 2015; Ford, McDougall, & Evans, 2009), both demonstrated positive and lasting effects on children's academic skills and self-regulatory behaviors in randomized controlled trials. In home visits, these interventions combined training on cognitively stimulating parenting with training on parenting practices that support behavioral self-regulation (including management practices that conceptually overlap with the autonomy supportive talk we observed in the present study). We speculate that the success of these intervention approaches is not only due to the fact that that the developmental domains are entwined, but also that the domains are entwined in *parenting*. More specifically, our findings of correlations between early math talk and management language are consistent with the conceptual notion of parenting profiles, whereby constellations of certain parenting practices are likely to co-occur within families. Attention to this may benefit the ecological validity of interventions aimed at changing parenting behaviors, including those with the ultimate goal of improving either math skills or executive functioning and self-regulation skills or all of the above.

Conclusion

In the present study, we find that parent number talk and management language are correlated within families, and most robustly so for autonomy supportive forms of management language and for parents who were not highly educated. These findings align with the notion that parenting practices may cluster together in meaningful ways (e.g., Bradley & Corwyn, 2004). In this case, our interest in the connections between number talk and management language was partly driven by the fact that: 1) number talk has proven to support children's math skills, 2) management language has proven to support EF skills, and 3) math and EF skills are themselves strongly correlated as early as three or four years of age. Beyond the likely cognitive interdependence of these two

domains, one reason for this early emerging relation may be correlated family supports within young children's early learning environments. Pursuing this line of work holds promise for gaining a better understanding of relevant developmental sequelae and, in turn, potential home and ECE interventions for children at risk in math, EF, or both.

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Appendix

Table A1
Parent number talk and management language examples.

Number talk	"How many times have you cut that now?" "Now there's two windows." "What's one more plus five?"
Management language	
Explicit directive	"Turn [the knife] this way. And hold it. And then cut." "Take [the duplos] all apart and put them back in."
Qualified directive	"We're going to play with these [duplos] after we read the book, okay?" "We're going to pick a different toy, okay?"
Ambiguous statement	"Can I start building something?" (after already starting to build with duplos) "You wanna [play with the watermelon] on the floor?" (while moving watermelon to the floor without child response)
Choice question	"Do you want to do Duplo's first or do you want to do those food stuff first?" "You want that [duplo] on top or on the bottom?"
Single suggestion	"Maybe cheese?" (in response to discussion about what to put on pretend sandwich) "How about a castle for Dorothy?" (in response to: "What should I build, Daddy?")
Transfer statement	"What do you want to build? Where do you want [this piece of cucumber] to go?"
Evocative events for directives and transfer statements	
Spontaneous explicit directive	Child: "I cut [the carrot] in half." Parent: "Okay, now you gotta plate it and serve it."
Child correction explicit directive	Child: Attempts to cut watermelon with knife upside down. Parent: "No, hold [the knife] this way." (turns knife in child's hand)
Child elicitation of explicit directive	Child: "Help." Parent: "Move it in there."
Spontaneous transfer statement	Child: "Where should this block go?" Parent: "Where do you want it to go?"
Child correction transfer statement	Parent: "We're not going outside right now. What else should we build?" (in response to child wandering)
Child elicitation of transfer statement	Child: "Can you build something for me?" Parent: "What do you want me to build you?"

Author note

All procedures involving human participants were in accordance with the ethical standards of the Boston College Institutional Review Board (reference 15.170.05) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Declarations of Competing Interest

None.

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