

Preschool Language Environments and Social Interactions in an Early Intervention Classroom: A Pilot Study

Stephanie A. Custode¹ , Jhonelle Bailey¹, Lei Sun¹,
Lynne Katz¹, MaryAnne Ullery¹, Daniel Messinger¹,
Rebecca J. Bulotsky-Shearer¹, and Lynn K. Perry¹

Abstract

Preschoolers' language abilities are associated with their social interactions in early childhood classrooms. Few studies, however, have examined associations between social interactions and objective measures of children's real-time classroom language environments, information key to informing interventions to support preschool children at risk for language delays. In this pilot study, we examined associations between objective measures of real-time language environments (input and output) recorded via the Language ENvironment Analysis (LENA) system and observations of children's positive and negative interactions with peers and teachers in an early intervention classroom for children with developmental delays ($n = 9$, seven girls). Mixed effects regression models revealed associations between children's language environments (input and output) and their social interactions with peers and teachers. More talkative children were more likely to have a high number of positive peer interactions. Children who received more language input from teachers were more likely to have a higher number of positive teacher–child interactions, an effect that was stronger for children with the lowest language output. The results of this pilot study build on prior research by using real-time objective measurement to examine how children's language input from peers and teachers and children's own language output supports positive interactions within early intervention classrooms.

Keywords

language environment, early social interactions, early intervention preschool classrooms, peer interaction, objective measurement

High quality preschool classroom environments are associated with positive developmental outcomes, particularly for children from at-risk backgrounds (Duncan et al., 2020; Sawyer et al., 2018). Multiple factors characterize high quality classrooms—including both structural factors (teacher training, child/teacher ratios, the physical environment) as well as process factors

¹University of Miami, Coral Gables, FL, USA

Corresponding Author:

Stephanie A. Custode, Department of Psychology, Princeton University, Peretsman Scully Hall, Princeton, NJ 08540, USA.

Email: stephanie.custode@gmail.com

(teacher–child and child-to-child interactions; NICHD Early Child Care Research Network, 2002). Process factors such as the quality of social interactions with teachers and peers provide a rich context for language development (Burchinal et al., 2008; Justice et al., 2014). However, we know less about how children’s language environment shapes opportunities for their social interactions.

Bronfenbrenner’s ecological theory (Bronfenbrenner & Morris, 2006) and Vygotsky’s socio-cultural theory (1978) provide models for understanding how children’s *language environments* contribute to development. In Bronfenbrenner’s model, children’s language and social development emerge in dynamic transactions. Not only do classrooms provide children with opportunities for language and social interaction, but this relationship is transactional: children’s own language abilities enable and elicit social interactions with others. For example, if children have delays understanding pragmatic aspects of language they may have difficulty using language during social interactions, which influences the development of social relationships with peers or teachers (Hollo et al., 2014).

Examining how classroom language environments facilitate social interactions is especially important for children from low-income backgrounds who may receive lower levels of language input at home and in the classroom (Hoff, 2013; Walker & Carta, 2020; Wright & Neuman, 2014; see Greenwood et al., 2020 for review), increasing their risk for language delays. Language delays and negative interactions with peers and teachers in classrooms often co-occur (see Chow & Wehby, 2018 for review).

Following Vygotsky’s theoretical model (1978), one potential explanation for this association is that language provides tools for navigating social interactions. Higher levels of language input and output can facilitate more positive social interactions with peers and teachers in the classroom. However, associations between classroom language environments and social interactions with peers and teachers remain unexplored. Identifying which aspects of children’s classroom language environments are associated with positive social interactions can set the stage for teacher-led interventions tailored to support children with language delays or difficulties. Aligning with ecological and transactional models, we conceptualize the *classroom language environment by the language input and output that children experience* using automated Language ENvironment Analysis (LENA; Gilkerson & Richards, 2009). *Language input* is measured by LENA estimates of the number of words children hear from teachers and the number of vocalizations children hear from peers. *Language output* is measured by LENA estimates of the number of vocalizations children produce (language output; King & Dockrell, 2016). To examine real-time associations between the classroom language environment and children’s social interactions, we conducted a pilot study, in an early intervention classroom for children with developmental delays.

Preschool Classroom Support of Development

Preschool classrooms are dynamic places where children interact with peers and teachers for multiple hours a day over weeks and months. Some of those social interactions are positive, some are negative. Positive peer social interactions include cooperative play, sharing, creative play, and shared positive affect; (Downer et al., 2010). Negative peer interaction may involve aggressive, disruptive, or disconnected behaviors, and display of negative affect (Bulotsky-Shearer et al., 2012). Positive social interactions with teachers involve shared positive affect and mutual engagement between teacher and child and negative interactions with teachers may involve negative affect, conflictual, noncompliant and inappropriate behavior, such as interrupting (Downer et al., 2010). Notably while interactions with peers and teachers can involve talking, they do not have to include talking to be considered an interaction.

Establishing peer relationships is an important developmental milestone for preschool children (Coolahan et al., 2000; Guralnick, 1993). Peer relationships and interactions within the classroom provide young children with opportunities to practice social skills and communicate with others; however, differences in children's language abilities are associated with differences in social interactions. Children who score higher on assessments of language ability tend to engage in a higher number of positive peer interactions than those with lower assessed language abilities (Mendez et al., 2002). Similarly, children with lower assessed language abilities tend to engage in a higher number of negative interactions with peers (Chow & Wehby, 2018) and are less likely to be integrated into classroom social networks than children with typically developing language abilities (Chen et al., 2019). Language abilities may be key skills necessary for children to successfully initiate and maintain social interactions with peers in the classroom (Ladd et al., 2012).

In addition to social interactions with peers, variations in children's language abilities are associated with their social interactions with teachers. Higher language abilities are associated with closer and more positive teacher-child relationships (Justice et al., 2008). In addition, preschool children with lower language abilities and lower temperamental shyness were rated by their teachers as higher in teacher conflict (Rudasill et al., 2006) and children with language delays were observed to engage in more negative interactions with teachers within the preschool classroom (Qi & Kaiser, 2004).

Overall, the evidence reviewed makes it clear that preschool children's language abilities are associated with positive and negative social interactions with peers and teachers in the classroom. However, few studies examine associations between what we conceptualize as the classroom language environment (individual children's language output and language input from peers and teachers) and their social interactions. It remains unclear whether or how children's own language output or input from peers and teachers influence their social interactions. To address this gap, our study examines associations between characteristics of real-time classroom language environments and moment-to-moment social interactions with peers and teachers.

A Framework for Understanding Associations Between Language and Social Interactions

Stronger language abilities may help children more successfully navigate social interactions within the classroom. Language is a tool that helps children express their ideas, needs, and emotions supporting positive and reducing negative interactions with peers and teachers (Chow & Wehby, 2018). Children also use language to self-regulate; those with weaker language abilities demonstrate difficulties regulating their emotions and behavior (Hentges et al., 2021), resulting in negative interactions with peers and teachers (Qi et al., 2020). Children who have poor expressive language skills may not be able to communicate their needs clearly, making it difficult for peers and teachers to understand and respond, creating fewer opportunities for positive interactions (Chow & Wehby, 2018; Cole et al., 2010). Despite theoretical and empirical support for the notion that language supports positive social interactions with peers and teachers, few studies investigate the association between *classroom language environments* and social interaction. We look to a series of recent studies that examine aspects of the classroom language environments to guide our work.

Classroom Language Environments

Language-rich environments, including language input and language output in both the home (Hoff, 2013) and school (Cabell et al., 2015; Mashburn et al., 2009) contribute to children's

language development. In the classroom, language input from teachers is positively associated with preschoolers' end-of-year assessed receptive and expressive language abilities (Farrow et al., 2020). In addition, the average language abilities of classroom peers in the fall of the school year positively predict children's spring language abilities after controlling for their language abilities in the fall (Justice et al., 2014), suggesting that language input from peers also plays a role in children's developing language abilities. Finally, when teachers' speech encourages children to respond during conversations, children have larger vocabulary gains (Cabell et al., 2015), suggesting children's own language output creates opportunities for learning. However, the majority of studies examining classroom language environments measure the *average* level of language used between children, peers, and teachers (Cabell et al., 2015; Mashburn et al., 2009), overlooking individual differences in language environments that exist, even within the same classroom (Perry et al., 2018). Averaging classroom effects restricts our ability to assess how the language of *each* member of a dyad contributes to interactions.

Individual Differences in Classroom Language Environments. In considering the role of language in social interaction not only is it necessary to consider the individual language abilities or language output of the target child, but it is also necessary to consider the contribution of the language abilities and output of each of their social partners. For example, is a child who generally produces more language *always* going to have positive interactions, or does the likelihood of having a positive interaction vary with how much their partner tends to talk? Historically, researchers have been limited in their ability to capture the variation across individuals and dyads, because they relied on labor-intensive manual transcriptions of spoken language.

The recent adoption of automated technologies, such as LENA, allow for efficient, naturalistic data collection and analysis of children's individual language environments. The LENA algorithm provides estimates of the number of vocalizations children produce (language output) and hear from other children (peer input) and adults (teacher input). Although most LENA research examines language environments in the home, a few recent studies use LENA recorders in preschool and early intervention classrooms (Fasano et al., 2021; Irvin et al., 2021; Perry et al., 2018, 2022). This research indicates that children's classroom language input from peers and teachers is associated with their own language output and their assessed language abilities.

Applications of LENA in Studying Social Interactions. LENA, when coupled with observation of children's classroom interactions, can be valuable for understanding associations between children's language environments and social interactions. Although few studies use this approach, a recent study that coupled LENA with automated measures of children's proximity to classroom peers found strong associations between the automated measures and teacher and child reports of children's reciprocal friendships (Altman et al., 2020). These findings highlight the value of using LENA to assess children's real-time classroom language environments and social interactions with peers and teachers.

Current Study

In this study, we used LENA to measure the classroom language environment (LENA-measured peer and teacher language input and child language output) and examined associations between children's classroom language environments and social interactions with peers and teachers in an early intervention classroom. We combined objective, automated measures of children's real-time language environments (LENA) with observed positive and negative social interactions with peers and teachers. All language measures refer to LENA-defined variables.

We examined four research questions:

Research Question 1 (RQ1): What are the associations between children's classroom language environments and observed peer interactions?

We hypothesized that children with higher rates of language output and children who received higher rates of peer and teacher language input would engage in a higher number of positive and a lower number of negative peer interactions.

Research Question 2 (RQ2): Are peer dyads' interactions associated with the quantity of each dyad member's language output (as measured from each of their LENA recorders)?

We hypothesized that dyads comprising children who both talk a lot (High-High) would have more positive and fewer negative interactions than dyads comprising children who both talk less (Low-Low) or dyads who differ in their levels of language output (High-Low).

Research Question 3 (RQ3): What are the associations between children's classroom language environments and observed teacher-child interactions?

We hypothesized that children's rates of language output and peer and teacher language input would be positively associated with the number of positive teacher-child interactions and negatively associated with the number of negative teacher-child interactions.

Research Question 4 (RQ4): Are teacher-child interactions associated with the quantity of *both* the child's language output and language input from the teacher?

We hypothesized that while in general children who receive more teacher language input will tend to have more positive and fewer negative teacher-child interactions than children who receive less teacher input, this effect will vary with children's levels of language output (High-Talkers or Low-Talkers), such that children who are High-Talkers will engage in similar high rates of positive and low rates of negative interactions, regardless of their teacher input. However, children who are Low-Talkers will show greater effects of teacher input such that those receiving higher teacher input will have more positive and fewer negative teacher-child interactions.

Method

Participants

Participants were nine monolingual English-learning, 2.5- to 3.5-year-old children ($M = 37$ months, range: 32–41 months) within one self-contained classroom in a center-based early intervention program providing services to children referred due to developmental risk factors such as prenatal substance exposure. All children in the classroom were consented for this study. All children qualified for free/reduced-price lunch and met criteria for services under Part C of the Individuals with Disabilities Education Act. When enrolled in the program, all children scored at least 1.5 standard deviations below the mean in two or more developmental domains, or two standard deviations below the mean in one developmental domain, as measured by the Battelle Developmental Inventory (BDI-2; Newborg, 2005). Participant demographic details are listed in Table 1.

Procedures

Data were collected once a week for five consecutive weeks. Because individual attendance varied, each child contributed 2- to 5-day-long recordings (see Table 1). On average, there were five

Table 1. Demographic Characteristics and PLS-5 Scores of Children in the Sample.

Participant	Age (months)	Race/Ethnicity	Sex	Recordings	PLS-5		
					Total	Expressive communication	Auditory comprehension
1	32	Multiracial	female	3	82	80	87
2	39	Black/African American	female	2	81	80	81
3	38	Black/Caribbean	male	3	92	100	86
4	41	Multiracial	female	4	84	91	82
5	34	Black/African American	female	3	91	95	89
6	39	Black/African American	female	5	100	97	103
7	37	Black/African American	female	2	95	100	91
8	35	Black/African American	male	2	74	26	79
9	41	Black/African American	female	3	90	95	84

Note. The Preschool Language Scales-5 (PLS-5) scores are standardized such that 100 is the 50th percentile. Scores from 85 to 115 indicate typical language ability. Four participants had total standard scores below 85 indicating possible language delay.

children and three adults, a primary teacher and two teaching assistants, present each observation day. During data collection, children's classroom language environments were recorded with LENA recorders, and a research member observed and coded children's social interactions with peers and teachers.

Measures

Assessed Language Abilities. Trained researchers administered the Preschool Language Scales, Fifth Edition (PLS-5; Zimmerman et al., 2011) at the end of each school year. The PLS-5 provides standardized measures of each child's receptive and expressive language abilities (scores on the auditory comprehension and expressive communication subscales, respectively, of the PLS-5; Zimmerman et al., 2011). PLS-5 scores are standardized such that 100 is considered typical for one's age, with scores < 85 (1 standard deviation below typical) indicating potential delay. Four of the nine participants in the study had total standard scores below 85 (see Table 1).

Direct Observation of Children's Social Interactions. A modified version of the *Child Interaction Scan Coding System* (adapted from Martin & Fabes, 2001; see Table 2) was used for direct observation of children's social interactions with peers and teachers. The pencil-and-paper interval coding system used a 30-second observation interval with a 10-second marking time (cued by a calibrated audio recording of "observe . . ." "record . . ." listened to with headphones), allowing observers to capture sequential observations of all children in the classroom. To capture children's interactions across multiple contexts of the preschool day, observers coded 10 observation cycles from the list of students (randomized for each data observation). Once all children were observed, the process was repeated, yielding 20 total observation cycles (10 minutes) per child, per observation day.

During each observation cycle, observers noted instances of the target child's interaction with proximal peer/s and/or teacher/s. Each instance of interaction was specified as either positive and/or negative, or neutral (partner within 1 m of target child but no indication of positive or negative behaviors). Social interactions were coded as positive if they involved cooperative play,

Table 2. Definitions and Procedures for Calculating Peer, Dyadic Peer, and Teacher–Child Scores From Direct Observation of Interactions.

Variable	Code descriptor	Score calculation examples
Peer Interactions		
Number of interactions	Coded when target child was in proximity (~1 m) with other children.	Sum of instance of peer interactions of child A to all peers during observations when A was the target child and when A was a peer to other target children.
Positive (proportion)	Coded during target child's peer interaction when either child displayed positive affect (e.g., smiling, laughing, sharing toys).	The number of positive interactions that the target child had with peers divided by the number of target child's peer interactions.
Negative (proportion)	Coded during target child's peer interaction when either child displayed negative affect (e.g., frowning, crying, furrowed brows).	The number of negative interactions that the target child had with peers divided by the number of target child's peer interactions.
Dyadic Peer Interactions		
Number of dyadic interactions	Coded when a pair of children was in proximity (~1 m) with each other.	Instances of dyadic interaction of a pair (e.g., A–B) was the sum of instances of A to B when A was the target child and B was the target child.
Dyadic positive (proportion)	Coded during dyadic interactions when either child displayed positive affect (e.g., smiling, laughing).	The sum of positive interactions of a specific dyad (e.g., A–B) divided by the sum of dyadic interactions of A to B across observations with A and B as the target child.
Dyadic negative (proportion)	Coded during dyadic interactions when either child displayed negative affect (e.g., frowning, crying).	The sum of negative interactions of a specific dyad (e.g., A–B) divided by the sum of dyadic interactions of A to B across observations with A and B as the target child.
Teacher–Child Interactions		
Number of interactions	Coded when target child was in proximity with teachers.	Sum of instances of teacher interactions of child A to teachers (3 teachers averaged).
Positive (proportion)	Coded during target child's teacher interaction when either displayed positive affect.	The sum of positive interactions between child and teachers divided by the number of target child's teacher interactions.
Negative (proportion)	Coded during target child's teacher interaction when either displayed negative affect.	The sum of negative interactions between target child and teachers divided by the number of target child's teacher interactions.

Note. Each observation coding period was 10 minutes. There was a total of six occasions when a dyadic interaction was coded as both positive and negative in the same interval, 4 times with peers (0.004% of peer interactions) and twice during teacher–child interactions (0.002% of teacher–child interactions). These intervals were tallied in both positive and negative interaction totals. Example coding sheet available at <https://osf.io/y9n7c>.

sharing, creative play, and shared positive affect. Social interactions were coded as negative if they involved aggressive, disruptive, disconnected or behaviors, or noncompliant and inappropriate behaviors, and display of negative affect. Both positive and negative codes could be used in a given 30-second cycle. For example, if the target child and a peer are playing with a toy and smiling but then begin fighting over the toy, the RA would code both a positive and negative interaction with that peer during that 30s interval. Positive and negative interactions were expressed as proportions of all instances of interactions (number of positive or negative interactions divided by the sum of positive, negative, and neutral) the child had that day with each peer and teacher. We chose this interval coding procedure rather than event or frequency coding because the behaviors coded were not typically discrete and could unfold over multiple seconds. See Table 2 for definitions and descriptions of score calculations.

In our observation coding scheme, children were both a target (child being observed) and a potential peer to other target children. To account for all interactions between children in each dyad, we added observations of interaction when each child within the dyad was the target (A:B + B:A) before averaging across all of target child's partners. For example, during observations in which Child A is the target, Child A could have three positive interactions with Child B. Later, during the same observation day, when Child B was the target, they had 1 positive interaction with Child A. Because teachers were not observed as targets, but only as potential partners, we only had observations of, e.g., Child A to Teacher 1 and not Teacher 1 to Child A. Thus, child-teacher observations did not need to be summed within a dyad before averaging.

Interobserver reliability (IOR) was obtained prior to data collection at 80% of a master coder. The two observers were trained on the observation procedure by a master coder (a senior graduate student). This training involved first watching classroom videos and practicing the observation coding procedure with feedback from the master coder. The observers then separately practiced observation coding in the study classroom, prior to the onset of study data collection. During these practices, one observer and the master coder both coded and then compared codes for reliability. The two observers had >80% IOR with the master coder after one practice. To control for observer drift and assess ongoing interobserver reliability, four observation days were double coded by both of these two observers. IOR both prior to and during the study was determined by calculating intraclass correlations (ICC) based on the ratings of children at each observation. Using the *ICC* function in the "psych" package in R (Revelle, 2022) a single rating, absolute agreement, two-way mixed-effects model yielded an ICC of .81 (95% CI = [.67, .90]), suggesting good agreement (Koo & Li, 2016).

Objective Measure of Children's Real-Time Classroom Language Environment. Audio from all children was recorded using LENA Digital Language Processors in specially designed vests. LENA recordings were collected once a week for the entirety of the school day ($M = 3.98$ hours) for a total of over 110 recorded classroom hours. Following data collection, audio files were analyzed using LENA Pro V3.4.0 pattern recognition software. Language environment measures were derived from LENA's Advanced Data Extractor (ADEX) codes of 5-minute segments. LENA software segments audio recordings into categories distinguishing children's own speech-like vocalizations from their non-speech sounds (e.g., crying), other speakers' vocalizations, and overlapping unintelligible speech.¹ To calculate language measures, we summed estimates for each day from each child's recorder and divided by the length of their recording to create daily rate measures of target child language output (using LENA child vocalization counts), peer language input (other child vocalizations), and teacher language input (adult word count). LENA measures of child language output and language input measured in both the home and preschool classrooms (Perry et al., 2018; Wang et al., 2020) have been shown to be a valid predictor of children's language abilities. As each participant was considered as both a target child and a peer, to facilitate comparisons of different peer dyads' general level of classroom language output, we

used each child's LENA measures of child language output to calculate their mean daily rate of talking, and then used median splits to classify each child as a "High-Talker" (High) or "Low-Talker" (Low). Child dyads were then classified as High-High (both children talked more than the median rate; Low-Low) both children talked less than the median; and High-Low (one child talked more, one less). Individual children could belong to multiple dyad types depending on who they interacted with—a High Talker could belong to both High-High and High-Low dyads. Teachers did not wear LENA recorders and we did not have individual measures of each teacher's overall rate of talking. We instead used median splits on children's own LENA's estimates of teacher input to consider relative differences in children's interactions with teachers, classifying them as receiving "High-input" or "Low-input" from teachers.

Analytic Approach

All analyses were conducted in *R* (R Core Team, 2015). Characterization of children's classroom language environments and social interactions with peers and teachers with respect to descriptive statistics and bivariate correlations can be found in the Supplemental Materials (Supplemental Tables S1 and S2 respectively). Our primary analyses examined the associations between language environments and social interactions. Linear mixed effects models were conducted using the *lmer* function in the "lme4" package (Bates et al., 2014). For all analyses, observations (Level 1) were nested within children (Level 2), using maximum likelihood estimation to account for missing data (Bates et al., 2014). Separate models predicted positive and negative interactions with peers and with teachers. We report coefficients, standard errors, and *t* values from each model and the results of chi-square tests of model fit, comparing models with and without each of the predictors of interest. All models had a random intercept of subject.

Results

RQ1: Associations Between Classroom Language Environments and Peer Interactions

Separate mixed effect models with observations nested in children predicted the proportion of children's (a) positive peer interactions and (b) negative peer interactions from their classroom language environment (peer and teacher language input, and child's language output). In the model predicting positive peer interactions, there was a significant effect of child language output, $B = 0.0007$, $SE = 0.0003$, $t = 2.29$; $\chi^2(1) = 4.38$, $p = .03$, such that children who had higher rates of language output engaged in a higher proportion of positive interactions with peers. Rates of peer, $p = .91$, and teacher input, $p = .64$, were not associated with children's positive interactions with peers (see Supplemental Table S3A for full model results). There were no significant effects of language output or input on the proportion of negative peer interactions (see Supplemental Table S3B).

RQ2: Variation in Peer Dyads' Language Output and Interactions

Using a median split based on LENA estimates of children's language output, we examined whether dyads composed of different combinations of High- and Low-Talkers differed in their interactions (Figure 1A and Figure 1B). Separate mixed effects models with observations nested in children predicted the proportion of positive and negative dyadic interactions from dyad talking levels (Low-Low, High-Low, or High-High). There was a significant main effect of dyad type on positive interactions, $\chi^2(2) = 11.31$, $p < .0001$. Follow up pairwise analyses indicated that High-High dyads had a higher proportion of positive interactions than High-Low dyads $B = 0.08$, SE

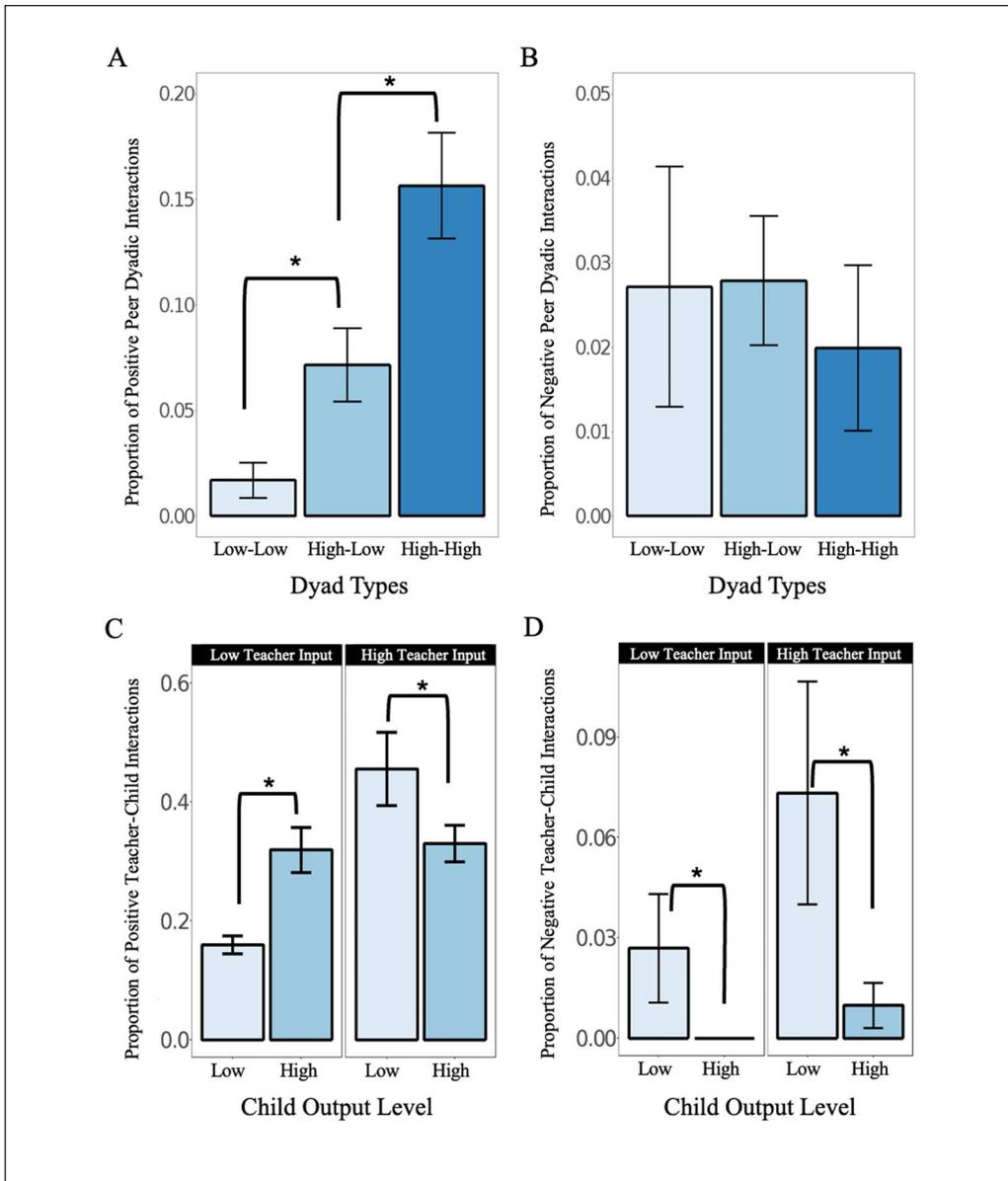


Figure 1. Top: Comparison of the Proportion of Positive Dyadic Peer Interactions (A) and the Proportion of Negative Dyadic Peer Interactions (B) Between Children of Each Dyad Type (Low-Talker & Low-Talker: High-Talker & Low-Talker: High-Talker & High-Talker). Bottom: Comparison of the Proportion of Positive Teacher-Child Interactions (C) and Proportion of Negative Teacher-Child Interactions (D) Between Teachers and Children With Varying Levels of Input/Output. Dyad Types and High/Low Input/Output Levels are Based on Median Splits Based on Children's Average Rates of Classroom Language Output and Teacher Language Input. Error Bars Represent Standard Error of Mean *Significant difference between group means.

= 0.02, $t = 2.96$; $\chi^2(1) = 13.40$, $p < .001$; and High-Low dyads had a higher proportion of positive interactions than Low-Low dyads, $B = 0.06$, $SE = 0.02$, $t = 2.26$; $\chi^2(1) = 7.88$, $p = .012$ (Figure 1A). There were no differences in the proportions of negative peer interactions between dyad types, $\chi^2(2) = 0.40$, $p = .68$ (Figure 1B). See Supplemental Table 3 for full model results.

RQ3. Associations Between Classroom Language Environments and Teacher–Child Interactions

We employed separate mixed effect models to predict the proportion of positive and negative teacher–child interactions from children’s language output and input from peers and teachers. We found a significant effect of teacher language input on the proportion of positive teacher–child interactions. The model predicting positive teacher–child interactions indicated a significant effect of teacher input, $B = 0.0003$, $SE = 0.0001$, $t = 3.09$; $\chi^2(1) = 9.22$, $p = .002$, such that children receiving higher rates of teacher input tended to engage in a higher proportion of positive teacher–child interactions than children receiving lower rates of teacher input. Children’s own vocalizations were not associated with their positive teacher–child interactions, $p = .89$, nor was their peer input, $p = .85$ (see Supplemental Table S3C for full model results). However, for negative teacher–child interactions, we found a significant negative effect of children’s language output, $B = -0.0005$, $SE = 0.0002$, $t = -2.03$; $\chi^2(1) = 4.45$, $p = .03$, such that children who vocalized *less* were involved in more negative interactions with their teachers. Children’s teacher, $p = .88$, and peer input, $p = .62$, were not associated with their negative teacher–child interactions (see Supplemental Table S3D).

RQ4. Variation in Teacher–Child Interactions With Language Output and Teacher Input

Using a median split based on each child’s LENA estimates of that child’s language output and teacher input, we examined how teacher–child interactions varied by level of child talk and teacher talk (Figures 1C and D). Separate linear mixed effect models with observations nested in children predicted the proportion of positive and negative teacher–child interactions from each child’s language output (High/Low), teacher language input (High/Low), and the interaction these terms. In predicting positive teacher–child interactions, we found only a marginal main effect of teacher input level, $B = -.02$, $SE = 0.01$, $t = -2.00$; $\chi^2(1) = 3.89$, $p = .050$, and no effect of child output level, $p = .258$. There was a significant interaction between child output and teacher input on the proportion of positive teacher–child interactions, $B = -0.05$, $SE = 0.02$, $t = -2.19$; $\chi^2(1) = 16.90$, $p < .0001$. See Table 3 for full model results. Follow-up analyses revealed that for children with high levels of teacher input, children who were Low-Talkers engaged in a higher proportion of positive teacher–child interactions than High-Talkers $B = -0.37$, $SE = 0.16$, $t = -2.37$, $\chi^2(1) = 5.73$, $p = .021$. Conversely, for children with low levels of teacher input, children who were High-Talkers engaged in higher proportions of positive teacher–child interactions than Low-Talkers, $B = -0.31$, $SE = 0.18$, $t = -2.21$, $\chi^2(1) = 5.12$, $p = .049$ (Figure 1C). Thus, when teacher input and child output were matching (e.g., Low-input/Low-Talker and High-input/High-Talker), there were relatively *low* levels of positive teacher–child interaction. Finally, although negative teacher–child interactions were infrequent, most of these negative interactions occurred between teachers and Low-Talkers, as evidenced by a significant main effect of child output level on the proportion of negative interactions, $B = .009$, $SE = 0.005$, $t = 2.03$; $\chi^2(1) = 4.24$, $p = .039$ (Figure 1D). There was no effect of teacher input level on negative teacher–child interactions, $p = .082$, nor any interaction between child output and teacher input, $p = .852$. See Table 3 for full model results.

Discussion

The goal of this pilot study was to examine associations between children’s classroom language environments and their social interactions with peers and teachers in an early intervention setting. We combined traditional observation methods with automated measures as a first step toward

Table 3. Results From Mixed Effects Models Predicting Proportion of Children's Positive and Negative Interactions With Peers (Research Questions 1 and 2) and Teachers (Research Questions 3 and 4).

Partner	Research question	Model outcome	Parameters	B	SE	t	χ^2	p			
Peers	RQ1	(A) Average daily proportion of positive peer interactions	Daily rate of child vocalizations	0.0007	0.0003	2.29	4.38	.036*			
			Daily rate of peer vocalizations	0.00002	0.0002	0.11	0.01	.91			
			Daily rate of teacher vocalizations	-0.00002	0.00003	-0.43	0.22	.64			
			Daily rate of child vocalizations	0.00003	0.0002	0.16	0.02	.88			
			Daily rate of peer vocalizations	0.0001	0.00008	1.62	2.92	.081			
Peers	RQ2	(A) Average daily proportion of positive peer interactions	Daily rate of teacher vocalizations	0.000005	0.00001	0.31	0.12	.734			
			Overall effect of dyad talking level	—	—	—	11.31	<.0001***			
			Overall effect of dyad talking level	—	—	—	.40	.68			
			Teacher	RQ3	(C) Average daily proportion of positive teacher interactions	Daily rate of child vocalizations	0.0001	0.001	0.09	0.02	.89
						Daily rate of peer vocalizations	-0.0001	0.0006	-0.18	0.51	.85
Daily rate of teacher vocalizations	0.0003	0.0001				3.09	9.22	.002***			
Daily rate of child vocalizations	-0.0005	0.0002				-2.03	4.45	.034*			
Daily rate of peer vocalizations	-0.00006	0.0001				-0.45	0.24	.62			
Teacher	RQ4	(D) Average daily proportion of positive teacher interactions	Daily rate of teacher vocalizations	0.000004	0.00002	0.15	0.02	.88			
			Teacher input level (High, Low)	-0.2	.01	-2.00	3.89	.050			
			Child output level (High, Low)	.01	.01	1.09	1.28	.258			
			Interaction between input and output levels	-0.05	.02	-2.19	16.90	<.0001***			
			Teacher input level (High, Low)	-0.08	.005	-1.66	2.92	.082			
Teacher	RQ4	(D) Average daily proportion of negative teacher interactions	Child output level (High, Low)	-0.31	.18	-2.21	5.12	.049			
			Interaction between input and output levels	-0.1	.009	-1.18	.93	.852			

Note. Bold faced values denote statistical significance as *p < .05, **p < .01, and ***p < .001.

understanding the role of classroom language environments in moment-to-moment social interaction. Children with higher rates of language output engaged in a higher number of positive peer interactions overall. Moreover, peer dyads with *two* High-Talkers engage in the most positive interactions of any dyad type. Children who received more teacher language input engaged in more positive teacher–child interactions than children who received less teacher input. This effect was stronger for children with lower levels of language output. Below we contextualize the findings as they comport with and extend prior research and discuss implications for early intervention classroom practice.

The Importance of Language in Supporting Social Interactions With Peers and Teachers

The findings support the idea that, for young children within an early intervention classroom, language is a tool for successful social interactions (Vygotsky, 1978). In this study, children who talked more engaged in a higher number of positive peer interactions, consistent with research suggesting that conversations with peers are the primary context in which children develop an appreciation of the principles of reciprocity and social exchange (Laursen et al., 1996). We also found that the social benefits of children’s language extended beyond the individual to the dyad. When both members of a dyad were High-Talkers (High–High), interactions were more positive than when both dyad members were Low-Talkers (Low–Low). Nevertheless, High–Low dyads engaged in more positive interactions than Low–Low dyads, suggesting a benefit for low-talkers to participate in mixed dyads. Interacting with a more talkative peer may be especially important for scaffolding positive interactions for children who talk less frequently. An interesting direction for future research would be investigating the role of teachers’ in facilitating positive peer interactions between dyads comprised of different language abilities.

Our finding that children who talked less tended to engage in a higher number of negative teacher–child interactions compared to children who talked more is consistent with previous research showing that children with language delays often exhibit more negative teacher–child interactions (Qi & Kaiser, 2004). It may be that children with lower language abilities do not have the tools to communicate their wants and needs to teachers, resulting in conflict and negative interactions. Interestingly, we found that children who produced low levels of language output also tended to have a higher number of positive teacher–child interactions—but *only* if they received high levels of teacher input. In other words, Low-Talkers who received high levels of teacher language input engaged in both more positive *and* more negative teacher–child interactions. It is possible that teachers intentionally change their behavior to support children they perceive as having lower language abilities, or that children with larger language delays are more receptive to teacher behaviors. In either case these results demonstrate how teachers, through their language use, could help facilitate and influence teacher–child interactions, especially for less talkative children. Overall, our findings could provide useful information about indices of children’s social interactions with peers and teachers in the classroom that could be utilized in an intervention context. For example, teacher scaffolding of sociodramatic or pretend play during free time within the classroom could be designed to enhance children’s play-based social interactions to promote rich language interactions for children with low language levels (Stanton-Chapman, 2015).

Limitations and Directions for Future Research

This pilot study was the first to explore associations between children’s observed social interactions with peers and with teachers and objectively measured classroom language environments.

The results, though promising, should be considered preliminary and represent a starting place for future studies. The primary limitation of our study is the small sample size (one early intervention classroom of nine children, with only two boys). Nevertheless, the study's intensive measurement design is a strength. Our data consisted of 5 day-long recordings over five consecutive weeks, yielded over 110 total hours of audio recording, an average of 3.98 hours per child per day. Future studies with a larger number of children and classrooms will help to assess generalizability across classrooms and activity contexts.

Our findings are consistent with research suggesting that language predicts social development (Chow & Wehby, 2018), however we measured language environments and social interaction concurrently, limiting directional inference. There is a potential bidirectional relationship between social interaction and language development in preschool classrooms (Bichay-Awadalla et al., 2020; Cashiola et al., 2020). Indeed, positive social interactions provide rich opportunities for children to develop receptive and expressive language skills. Future studies can extend our findings with longitudinal assessments of changes in language and social skills to better understand their association.

In addition, although we found meaningful variability in children's language output in the classroom, the children in our sample all had developmental delays, and many had language delays, with the highest PLS-5 scores only falling at the 50th percentile for age, and many falling significantly lower (see Table 1). Thus, "High-Talkers" were high relative to their classmates but not relative to children their age in general. Future research should examine associations between language environments and social interactions in *inclusive* classrooms where typically developing peer models and children with delays interact (Mok et al., 2014). Relatedly, all children in our classroom came from low-SES backgrounds. Given the previously documented gap between language abilities in children from low- and high-SES backgrounds, it will also be important for future work in intervention and inclusion classrooms to include children with different cultural, linguistic, and SES background to better understand how to support a diversity of children with delays (cf. Greenwood et al., 2020; Walker & Carta, 2020).

Finally, we characterized the classroom language environment based on rates of talking by child, peers, and teachers. Although this quantification of language was associated with children's social interactions, we still do not know how the content of that language or children's specific language skills with respect to phonology, semantics, morphosyntax, and pragmatics influence social interactions in the classroom. Future work is needed to understand the underlying language mechanisms supporting positive social interactions.

Implications for Early Childhood Intervention

Teachers' language plays a vital role in shaping classroom environments by establishing rules for social interactions, managing challenging or negative interactions among children, and scaffolding children's positive interactions (Farmer et al., 2011; Whorrall & Cabell, 2016). Although preliminary, our findings have implications for educational practice by providing a research-based foundation for strategies that teachers can use to support positive interactions. Following the finding that children who talked less engaged in more positive interactions when interacting with a more talkative peer, teachers could pair peers with different levels of language abilities during classroom activities. This intentional pairing, similar to existing peer-mediated classroom interventions aimed at increasing positive reciprocal peer interactions, such as the Play Buddy (Fantuzzo et al., 2005) and Stay-Play-Talk (Goldstein et al., 2007) interventions, may benefit children's language and social development. With respect to teachers' own interactions with children, the current findings suggest children who talked less benefited the most when receiving high levels of teacher language input. When interacting with a child with lower language skills,

teachers can be mindful of how the input they provide can not only support that child's language abilities but can also encourage positive social interactions.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was funded by grants from the National Science Foundation #1620294 and the Institute of Education Sciences #R324A180203 awarded to Daniel Messinger. We thank Krystal Bichay-Awadalla, Adriana Valtierra, and Klara Jansova for assistance with data collection and coding.

ORCID iD

Stephanie A. Custode  <https://orcid.org/0000-0002-5078-6350>

Supplemental Material

Supplemental material for this article is available online.

Data Availability

The data that support the findings of this study are available on the Open Science Framework <https://osf.io/y9n7c/>

Note

1. To investigate whether classification of overlapping speech differed across children in ways that could skew data, we calculated the proportion of time in each 5-min ADEX segment that was coded as OLN (LENA estimates of overlapping speech). Overall, the average per segment was 39%. We compared the proportion of overlap on each individual child's recordings to investigate whether audio classified as overlapping speech systematically differed across children with respect to their talkativeness. A two-tailed *t*-test did not reveal any significant differences in the proportion of overlap on High-Talkers' recordings ($M = .38$) and Low-Talkers' recordings ($M = .40$), $p = .43$. Thus, overlapping speech was not systematically different across groups.

References

- Altman, R., Laursen, B., Messinger, D. S., & Perry, L. K. (2020). Validation of continuous measures of peer social interaction with self- and teacher-reports of friendship and social engagement. *European Journal of Developmental Psychology, 17*, 773–785.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48.
- Bichay-Awadalla, K., Qi, C. H., Bulotsky-Shearer, R. J., & Carta, J. J. (2020). Bidirectional relationship between language skills and behavior problems in preschool children from low-income families. *Journal of Emotional and Behavioral Disorders, 28*(2), 114–128. <https://doi.org/10.1177/1063426619853535>
- Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology: Theoretical models of human development* (pp. 793–828). Wiley.
- Bulotsky-Shearer, R. J., Bell, E. R., Romero, S. L., & Carter, T. M. (2012). Preschool interactive peer play mediates problem behavior and learning for low-income children. *Journal of Applied Developmental Psychology, 33*(1), 53–65. <https://doi.org/10.1016/j.appdev.2011.09.003>
- Burchinal, M., Howes, C., Pianta, R., Bryant, D., Early, D., Clifford, R., & Barbarin, O. (2008). Predicting child outcomes at the end of kindergarten from the quality of pre-kindergarten teacher–

- child interactions and instruction. *Applied Developmental Science*, 12(3), 140–153. <https://doi.org/10.1080/10888690802199418>
- Cabell, S. Q., Justice, L. M., McGinty, A. S., DeCoster, J., & Forston, L. D. (2015). Teacher–child conversations in preschool classrooms: Contributions to children’s vocabulary development. *Early Childhood Research Quarterly*, 30(Part A), 80–92. <https://doi.org/10.1016/j.ecresq.2014.09.004>
- Cashiola, E., Bulotsky-Shearer, R., & Greenfield, D. (2020). Bidirectional associations between problem behavior and language and literacy skills in Head Start children. *Topics in Early Childhood Special Education*, 40, 140–158.
- Chen, J., Lin, T.-J., Justice, L., & Sawyer, B. (2019). The social networks of children with and without disabilities in early childhood special education classrooms. *Journal of Autism and Developmental Disorders*, 49(7), 2779–2794. <https://doi.org/10.1007/s10803-017-3272-4>
- Chow, J. C., & Wehby, J. H. (2018). Associations between language and problem behavior: A systematic review and correlational meta-analysis. *Educational Psychology Review*, 30(1), 61–82. <https://doi.org/10.1007/s10648-016-9385-z>
- Cole, P. M., Armstrong, L. M., & Pemberton, C. K. (2010). The role of language in the development of emotion regulation. In S. D. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 59–77). American Psychological Association. <https://doi.org/10.1037/12059-004>
- Coolahan, K., Fantuzzo, J., Mendez, J., & McDermott, P. (2000). Preschool peer interactions and readiness to learn: Relationships between classroom peer play and learning behaviors and conduct. *Journal of Educational Psychology*, 92, 458–465. <https://doi.org/10.1037/0022-0663.92.3.458>
- Downer, J., Sabol, T. J., & Hamre, B. (2010). Teacher–child interactions in the classroom: Toward a theory of within- and cross-domain links to children’s developmental outcomes. *Early Education and Development*, 21(5), 699–723. <https://doi.org/10.1080/10409289.2010.497453>
- Duncan, R. J., King, Y. A., Finders, J. K., Elicker, J., Schmitt, S. A., & Purpura, D. J. (2020). Prekindergarten classroom language environments and children’s vocabulary skills. *Journal of Experimental Child Psychology*, 194, Article 104829. <https://doi.org/10.1016/j.jecp.2020.104829>
- Fantuzzo, J., Manz, P., Atkins, M., & Meyers, R. (2005). Peer-mediated treatment of socially withdrawn maltreated preschool children: Cultivating natural community resources. *Journal of Clinical Child & Adolescent Psychology*, 34(2), 320–325. https://doi.org/10.1207/s15374424jccp3402_11
- Farmer, T. W., McAuliffe Lines, M., & Hamm, J. V. (2011). Revealing the invisible hand: The role of teachers in children’s peer experiences. *Journal of Applied Developmental Psychology*, 32(5), 247–256. <https://doi.org/10.1016/j.appdev.2011.04.006>
- Farrow, J., Wasik, B. A., & Hindman, A. H. (2020). Exploring the unique contributions of teachers’ syntax to preschoolers’ and kindergarteners’ vocabulary learning. *Early Childhood Research Quarterly*, 51, 178–190. <https://doi.org/10.1016/j.ecresq.2019.08.005>
- Fasano, R. M., Perry, L. K., Zhang, Y., Vitale, L., Wang, J., Song, C., & Messinger, D. S. (2021). A granular perspective on inclusion: Objectively measured interactions of preschoolers with and without autism. *Autism Research*, 14(8), 1658–1669. <https://doi.org/10.1002/aur.2526>
- Gilkerson, J., & Richards, J. A. (2009). *The LENA Foundation natural language study* (LENA Foundation Technical Report No. LTR-02-2). http://www.lenafoundation.org/TechReport.aspx/Natural_Language_Study/LTR-02-2
- Goldstein, H., Schneider, N., & Thiemann, K. (2007). Peer-mediated social communication intervention: When clinical expertise informs treatment development and evaluation. *Topics in Language Disorders*, 27(2), 182–199. <https://doi.org/10.1097/01.TLD.0000269932.26504.a8>
- Greenwood, C. R., Schnitz, A. G., Carta, J. J., Wallisch, A., & Irvin, D. W. (2020). A systematic review of language intervention research with low-income families: A word gap prevention perspective. *Early Childhood Research Quarterly*, 50, 230–245. <https://doi.org/10.1016/j.ecresq.2019.04.001>
- Guralnick, M. J. (1993). Developmentally appropriate practice in the assessment and intervention of children’s peer relations. *Topics in Early Childhood Special Education*, 13(3), 344–371. <https://doi.org/10.1177/027112149301300310>
- Hentges, R. F., Devereux, C., Graham, S. A., & Madigan, S. (2021). Child language difficulties and internalizing and externalizing symptoms: A meta-analysis. *Child Development*, 92, e691–e715. <https://doi.org/10.1111/cdev.13540>

- Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Developmental Psychology, 49*(1), 4–14. <https://doi.org/10.1037/a0027238>
- Hollo, A., Wehby, J. H., & Oliver, R. M. (2014). Unidentified language deficits in children with emotional and behavioral disorders: A meta-analysis. *Exceptional Children, 80*(2), 169–186. <https://doi.org/10.1177/001440291408000203>
- Irvin, D. W., Luo, Y., Huffman, J. M., Grasley-Boy, N., Rous, B., & Hansen, J. H. L. (2021). Capturing talk and proximity in the classroom: Advances in measuring features of young children's friendships. *Early Childhood Research Quarterly, 57*, 102–109. <https://doi.org/10.1016/j.ecresq.2021.05.003>
- Justice, L. M., Logan, J. A. R., Lin, T.-J., & Kaderavek, J. N. (2014). Peer effects in early childhood education: Testing the assumptions of special-education inclusion. *Psychological Science, 25*(9), 1722–1729. <https://doi.org/10.1177/0956797614538978>
- Justice, L. M., Mashburn, A., Hamre, B., & Pianta, R. (2008). Quality of language and literacy instruction in preschool classrooms serving at-risk pupils. *Early Childhood Research Quarterly, 23*(1), 51–68. <https://doi.org/10.1016/j.ecresq.2007.09.004>
- King, S. E., & Dockrell, J. E. (2016). Investigating affordance of opportunity for young children's language interactions in a nursery setting: How can small group talk act as a forum for language learning? *Journal of Early Childhood Research, 14*(4), 351–369. <https://doi.org/10.1177/1476718X14552877>
- Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163. <https://doi.org/10.1016/j.jcm.2016.02.012>
- Ladd, G. W., Kochenderfer-Ladd, B., Visconti, K. J., & Ettekal, I. (2012). Classroom peer relations and children's social and scholastic development: Risk factors and resources. In A. M. Ryan & G. W. Ladd (Eds.), *Peer relationships and adjustment at school* (pp. 11–49). IAP Information Age Publishing.
- Laursen, B., Hartup, W. W., & Koplas, A. L. (1996). Towards understanding peer conflict. *Merrill-Palmer Quarterly, 42*(1), 76–102.
- Martin, C. L., & Fabes, R. A. (2001). The stability and consequences of young children's same-sex peer interactions. *Developmental Psychology, 37*(3), 431–446. <https://doi.org/10.1037/0012-1649.37.3.431>
- Mashburn, A. J., Justice, L. M., Downer, J. T., & Pianta, R. C. (2009). Peer effects on children's language achievement during pre-kindergarten. *Child Development, 80*(3), 686–702. <https://doi.org/10.1111/j.1467-8624.2009.01291.x>
- Mendez, J. L., Fantuzzo, J., & Cicchetti, D. (2002). Profiles of social competence among low-income African American preschool children. *Child Development, 73*(4), 1085–1100. <https://doi.org/10.1111/1467-8624.00459>
- Mok, P. L. H., Pickles, A., Durkin, K., & Conti-Ramsden, G. (2014). Longitudinal trajectories of peer relations in children with specific language impairment. *Journal of Child Psychology and Psychiatry, 55*(5), 516–527. <https://doi.org/10.1111/jcpp.12190>
- Newborg, J. (2005). *Battelle Developmental Inventory* (2nd ed.). Riverside.
- NICHD Early Child Care Research Network. (2002). Early child care and children's development prior to school entry: Results from the NICHD study of early child care. *American Educational Research Journal, 39*(1), 133–164. <https://doi.org/10.3102/00028312039001133>
- Perry, L. K., Mitsven, S. G., Custode, S., Vitale, L., Laursen, B., Song, C., & Messinger, D. S. (2022). Reciprocal patterns of peer speech in preschoolers with and without hearing loss. *Early Childhood Research Quarterly, 60*, 201–213. <https://doi.org/10.1016/j.ecresq.2022.02.003>
- Perry, L. K., Prince, E. B., Valtierra, A. M., Rivero-Fernandez, C., Ullery, M. A., Katz, L. F., Laursen, B., & Messinger, D. S. (2018). A year in words: The dynamics and consequences of language experiences in an intervention classroom. *PLOS ONE, 13*(7), Article e0199893. <https://doi.org/10.1371/journal.pone.0199893>
- Qi, C. H., Horn, M. L. V., Selig, J. P., & Kaiser, A. P. (2020). Relations between language skills and problem behaviour in preschool children. *Early Child Development and Care, 190*(16), 2493–2504. <https://doi.org/10.1080/03004430.2019.1588264>
- Qi, C. H., & Kaiser, A. P. (2004). Problem behaviors of low-income children with language delays. *Journal of Speech, Language, and Hearing Research, 47*(3), 595–609. [https://doi.org/10.1044/1092-4388\(2004/046\)](https://doi.org/10.1044/1092-4388(2004/046))

- R Core Team. (2015). R: A language and environment for statistical computing.
- Revelle, W. (2022). *psych: Procedures for psychological psychometric, and personality research* (Version 2.2.9) [Computer software].
- Rudasill, K. M., Rimm-Kaufman, S. E., Justice, L. M., & Pence, K. (2006). Temperament and language skills as predictors of teacher-child relationship quality in preschool. *Early Education and Development, 17*(2), 271–291. https://doi.org/10.1207/s15566935eed1702_4
- Sawyer, B., Atkins-Burnett, S., Sandilos, L., Hammer, C. S., Lopez, L., & Blair, C. (2018). Variations in classroom language environments of preschool children who are low income and linguistically diverse. *Early Education and Development, 29*(3), 398–416. <https://doi.org/10.1080/10409289.2017.1408373>
- Stanton-Chapman, T. L. (2015). Promoting positive peer interactions in the preschool classroom: The role and the responsibility of the teacher in supporting children's sociodramatic play. *Early Childhood Education Journal, 43*(2), 99–107. <https://doi.org/10.1007/s10643-014-0635-8>
- Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Walker, D., & Carta, J. J. (2020). Intervention research to improve language-learning opportunities and address the inequities of the word gap. *Early Childhood Research Quarterly, 50*, 1–5. <https://doi.org/10.1016/j.jecresq.2019.10.008>
- Wang, Y., Williams, R., Dilley, L., & Houston, D. M. (2020). A meta-analysis of the predictability of LENATM automated measures for child language development. *Developmental Review, 57*, Article 100921. <https://doi.org/10.1016/j.dr.2020.100921>
- Whorrall, J., & Cabell, S. Q. (2016). Supporting children's oral language development in the preschool classroom. *Early Childhood Education Journal, 44*(4), 335–341. <https://doi.org/10.1007/s10643-015-0719-0>
- Wright, T. S., & Neuman, S. B. (2014). Paucity and disparity in kindergarten oral vocabulary instruction. *Journal of Literacy Research, 46*(3), 330–357. <https://doi.org/10.1177/1086296X14551474>
- Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). Preschool language scales—fifth edition. <https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-Assessments/Developmental-Early-Childhood/Development/Preschool-Language-Scales-%7C-Fifth-Edition/p/100000233.html>