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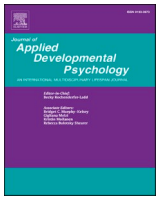

Beyond the sandbox: Lasting associations of preschool peer language skills with third-grade vocabulary and the role of primary school peers

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ABSTRACT

While emerging evidence links peer group composition to children's language development, most studies are limited to short-term effects and rarely examine potential long-term patterns across educational stages in which children encounter different peer groups. This study examined whether the average language skills of preschool peers showed a lasting association with children's receptive vocabulary in third grade, and further explored whether subsequent primary school peer groups added to or moderated this association. Using data from the German National Educational Panel Study (NEPS; $n = 499$ target children in 213 preschool groups and 190 primary school classrooms), we applied multilevel regression analyses accounting for children's baseline vocabulary, sociodemographic characteristics, and the nested structure of the data. Preschool peer language skills showed a modest positive association with later vocabulary, which was moderated by primary school peer group skills. Contrary to expectations, preschool effects were strongest when children entered lower-skilled primary school peer groups and were not detectable in higher-skilled groups. No independent additive effect of primary school peer skills emerged. These findings suggest that preschool peer groups may serve as a compensatory foundation when later peer environments are less supportive and underscore the importance of considering consecutive peer contexts when examining longer-term associations in language development.

Early peer environments can have remarkably long-term effects, extending well beyond childhood to outcomes such as college attendance and adult earnings (Carrell et al., 2018; Chetty et al., 2011). Such findings underscore the lasting importance of early peer contexts and raise the question of how peer group characteristics shape development as children progress through different educational stages and encounter new peer groups. The transition from preschool to formal schooling marks one such critical shift in children's educational trajectory (Rimm-Kaufman & Pianta, 2000). This period is also formative for language development, a domain that is particularly sensitive to environmental input (Rowe & Weisleder, 2020), and foundational for a wide range of learning and developmental outcomes (Bleses et al., 2016; Wieczorek et al., 2025).

Despite the key role peers play in children's daily experiences, their contribution to language development has received relatively little attention compared to the extensive body of research on family environment (Anderson et al., 2021) and teacher-related influences (Dickinson & Porche, 2011; Justice et al., 2018). Emerging evidence suggests that peer group composition in early education may relate to children's language skills (Henry & Rickman, 2007; Mashburn et al., 2009; Reid & Ready, 2013). However, findings remain mixed and are largely limited to short-term effects within single educational settings (Kohl et al., 2022; Yang et al., 2023). Surprisingly, little is known about how peer group composition in early childhood relates to later language skills and how changing peer contexts may modify such long-term effects across educational transitions. Yet understanding the lasting effects of early peer composition and the interplay of successive peer environments is key to supporting sustained language development. To address these gaps, the present study investigated whether the average language skills of children's preschool peer groups predict their receptive vocabulary in third grade, and whether the subsequent peer environment after the transition to primary school contributes to, amplifies, or attenuates this association.

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Peer composition effects in educational contexts

The term *peer effect* is commonly used to describe how peer groups may influence individual development and learning, whether through direct interaction, shared experiences, or broader contextual factors (Sacerdote, 2011). This study adopts a compositional perspective, examining associations between individual outcomes and aggregated group-level characteristics (Raudenbush & Bryk, 2002), specifically the average language skills of children's peer groups. Although such compositional measures do not directly capture causal processes or specific mechanisms, they serve as meaningful indicators of the social environments in which development unfolds. This perspective draws on Bronfenbrenner's bioecological model (Bronfenbrenner & Morris, 2006), which conceptualizes development as driven by proximal processes within immediate environments over time. Peer groups form a central part of the microsystem, where their aggregated characteristics may shape the quality and dynamics of children's everyday experiences. In parallel, social learning theory (Bandura, 1971) points out potential mechanisms of influence, emphasizing how children may acquire skills and behaviors through observation and imitation of peers in these everyday contexts. For example, peers with higher language skills may offer more opportunities for verbal interaction and exposure to complex language, potentially supporting individual vocabulary growth. Indirect mechanisms may also be relevant, if peer composition shapes classroom processes, teacher practices, or the overall learning environment, which in turn can influence individual development (Pakarinen et al., 2011; Rjosk et al., 2014).

Most research on educational composition effects has focused on academic achievement in school-aged children, reporting that students often benefit academically when surrounded by high-achieving or socioeconomically advantaged classmates, even after controlling for individual characteristics (Becker et al., 2022; Van Ewijk & Sleegers, 2010). More recently, studies have extended this focus to younger children and a broader set of developmental domains, such as behavior (Ribeiro et al., 2017), executive functions (Weiland & Yoshikawa, 2014; Yang et al., 2023), and academic skills (Bier et al., 2025; Henry & Rickman, 2007). While positive associations between peer group composition and children's outcomes have been documented, the overall picture remains inconsistent across domains, individual characteristics, and methodologies. Nevertheless, this research demonstrates that the composition of learning environments can play a role in shaping children's development.

One domain where such effects have become a growing line of research, particularly in early education, is language development. Children orient toward salient social groups as reference contexts for language, adopting linguistic features such as accent and dialect from the groups they identify with (Stanford, 2008). In early educational settings, peer groups represent such a central context, with children's language use converging through frequent interactions (Nardy et al., 2014). While this research highlights peer influences on sociolinguistic variation, a related question is whether differences in peer language skills contribute to variation in children's language competencies.

Evidence of peer effects on language development

Children enter early educational settings with considerable differences in language abilities (Fernald et al., 2013), largely shaped by the linguistic input they receive (Anderson et al., 2021; Rowe, 2012). Since early language skills robustly predict later literacy and academic success (Bleses et al., 2016), supporting language competencies is a major concern in early education (OECD, 2024; Sylva et al., 2015). In this context, numerous studies have examined how early education and care (ECEC) environments relate to variation in language development, focusing primarily on structural and process quality (Keys et al., 2013; Ulferts et al., 2019).

Studies on peer-related features often examine demographics such as socioeconomic status or home language. While these characteristics are well-established predictors at the individual level, findings on their group-level effects are mixed (Kohl et al., 2019; Kohl et al., 2022; Lin et al., 2023; Reid & Ready, 2013; Weiland & Yoshikawa, 2014). Given the substantial amount of time children spend with peers, the language skills of the peer group may more directly capture the quantity and quality of language input (Foster et al., 2020; Kohl et al., 2022; Lin et al., 2023). Accordingly, some studies suggest that children in groups with higher mean language skills tend to make greater progress than comparable peers in lower-skilled classrooms (Lin et al., 2023; Mashburn et al., 2009), though others report no significant association (Kohl et al., 2022; Yang et al., 2023), or effects limited to specific groups, such as dual language learners (DLL; Schmerse, 2021), children of less educated mothers (Ribeiro et al., 2017) or those with initially low skills (Justice et al., 2011).

Beyond preschool, primary school studies on peer effects have mainly addressed literacy outcomes like reading and spelling (Gottfried, 2014; Kuzmina & Ivanova, 2018; Luyten et al., 2009), which are highly relevant indicators of children's developing language skills in school years. While peer composition has been linked to such academic language related outcomes, some studies also found associations with vocabulary skills during primary school. For example, Quinn et al. (2018) demonstrated that classroom peer vocabulary levels were positively associated with individual vocabulary gains in early primary school, particularly among children in the lower part of the achievement distribution. Taking a broader perspective on both preschool and primary school contexts, a recent integrative analysis of six German longitudinal studies documented substantial variability in peer effects, with meta-analytic aggregation identifying a robust effect for children with lower initial language abilities (Hürlimann et al., 2025).

Overall, growing evidence points to the relevance of peer composition for language development, though associations differ considerably across studies and most examine relatively brief timeframes. While a few exceptions have adopted longer observation periods (Luyten et al., 2009; Schmerse, 2021), these studies do not systematically consider changes in peer composition across educational settings. Thus, important gaps remain about early peer composition effects beyond the initial setting and the role of subsequent peer contexts.

Long-term effects of early educational contexts

A substantial body of research demonstrates that early educational experiences can have lasting effects on developmental trajectories and later life outcomes (Dickinson & Porche, 2011; McCoy et al., 2017; Vandell et al., 2010). High ECEC quality – including structural features (e.g., group size, teacher qualifications) and process quality (e.g., instructional practices, teacher-child interactions) – has emerged as a particularly important predictor of long-term outcomes, with evidence for language-related skills as well (Belsky et al., 2007; Ulferts et al., 2019). However, other research has found declining preschool effects or fadeout (Lipsey et al., 2018; Peisner-Feinberg et al., 2001), raising the question of whether long-term effects depend on both the early educational context and characteristics of subsequent environments (Abenavoli, 2019; Ansari & Pianta, 2018a; Magnuson et al., 2007).

While this literature has primarily focused on structural and process quality dimensions, less is known about whether other features of early educational contexts, such as peer group composition, show similarly lasting associations. Some studies within primary school settings suggest that peer characteristics may also be linked to academic outcomes over several years (Luyten et al., 2009; Neidell & Waldfogel, 2010). For example, children who spent kindergarten in classrooms with more classmates who had previously attended preschool showed higher reading and math achievement through third grade (Neidell & Waldfogel, 2010). Given that the compositional measure captures the share of peers with prior preschool experience, this study further provides evidence consistent with longer-term spillover effects of preschool

participation.

Fewer studies examine whether early peer composition predicts outcomes beyond the initial context. Chetty et al. (2011), for instance, reported that assignment to higher-achieving classrooms in kindergarten and early primary school relates to college attendance and higher adult earnings. Carrell et al. (2018) found that early exposure to more peers with a history of documented domestic violence negatively predicted long-term academic and labor market outcomes. Evidence specifically on language development remains scarce. Schmerse (2021) showed that DLL children in preschool peer groups with higher skills in the majority language exhibited stronger growth in majority-language vocabulary into first grade. Though this timeframe remains relatively short, the finding suggests that peer composition may shape language trajectories beyond the immediate setting.

In sum, early educational contexts can have lasting effects on children's development, including language, but such effects are not uniform and may relate to later environments (Ansari & Pianta, 2018a). Evidence on peer composition points to long-term links as well, yet findings on language are sparse. Given that peer composition typically changes with school entry, subsequent peer contexts might alter how earlier peer effects unfold.

Joint effects of successive educational environments

Children's development takes place across a series of educational settings that may exert joint influences that accumulate or interact over time. Preschool peers and subsequent primary school peers, for instance, may be linked to language development through additive patterns—where each setting shows independent associations—or interactive patterns, such that associations with early preschool peer groups depend on the characteristics of later primary school peer environments.

Moderating patterns are supported by theoretical frameworks such as the *sustaining environments hypothesis* (SEH; Bailey et al., 2017), which posits that early developmental gains are more likely to persist when followed by high-quality environments but may fade in less supportive ones. Notably, quality is broadly understood at both classroom and school level, encompassing structural and instructional features, social support, curricular continuity, teacher quality, and peer indicators such as average achievement level (Bailey et al., 2020).

Empirical support for the SEH has primarily come from evaluations of targeted programs, early interventions, and preschool attendance, where lasting benefits of participation were found to be contingent on the quality of later settings (Ansari & Pianta, 2018a; Pearman et al., 2020; Swain et al., 2015). Recently, the composition of subsequent peer groups has received growing attention as a potential sustaining factor (Botvin et al., 2024; Burchinal et al., 2023; List & Uchida, 2024; Shea et al., 2025), with studies typically examining whether the proportion of preschool attenders or children with intervention experiences helps maintain or reinforce the initial preschool impacts.

Although the SEH was developed to explain persistence of intervention effects, its core idea that subsequent environmental factors moderate early effects may extend to naturally occurring variations in consecutive educational contexts (Ansari & Pianta, 2018b; Han et al., 2020). Some studies have examined interactions between preschool and primary school classroom quality measures on long-term outcomes and have identified moderating effects consistent with the SEH (Ansari & Pianta, 2018b; Carr et al., 2019). For example, Ansari and Pianta (2018b) demonstrated that early child care quality predicted language and literacy in 5th and 9th grade only when followed by high-quality primary school classrooms.

A few studies have also reported additive effects, with both early and later classroom quality contributing independently to children's development (Ansari & Pianta, 2018b; Carr et al., 2019; Lehrl et al., 2016). While some of these findings pertain to mathematical skills, Carr et al. (2019) showed such effects specifically for language and literacy outcomes. However, other research across domains and quality measures found no support for either additive or moderating patterns (Anders et al., 2013; Han et al., 2020; Johnson et al., 2025). Moreover, in a recent meta-analysis, Bailey et al. (2020) concluded that evidence for sustained effects of later quality is limited, possibly due to methodological limitations.

Overall, evidence on sustaining environments, including peer-related factors, raises important questions about the long-term reach of peer effects. If preschool peer composition influences language development, the presence and magnitude of such associations may depend on later peer group characteristics. Similarly high-skilled peers may offer richer linguistic input and more opportunities for elaborated language use, potentially building on earlier gains, while lower-skilled peer groups may limit such opportunities, thereby reducing the longer-term salience of early peer effects. Later peer composition could also contribute additively, exerting its own influence on language growth over and above earlier peer exposure. However, to the best of our knowledge, no study has systematically examined naturally occurring peer language composition across both preschool and primary school to assess whether and how these successive contexts jointly shape long-term language outcomes.

The present study

While peer effects in early education have received growing attention, their longer-term significance, particularly in light of changing peer contexts, remains underexplored. The present study aimed to examine whether preschool peer language composition is associated with later vocabulary outcomes and whether subsequent peer groups contribute to or modify these associations. We focus on receptive vocabulary as the primary outcome in third grade because it represents a foundational component of language development that supports reading comprehension and broader academic skills (e.g., Verhoeven et al., 2011). Vocabulary knowledge is also strongly shaped by cumulative language exposure in everyday environments, including interactions with peers, making it particularly relevant for examining peer composition effects. In addition, receptive vocabulary allows for a consistent operationalization of language skills across developmental periods, from preschool to primary school.

Drawing on data from a German longitudinal panel study and using multilevel regression models, we address three research questions (RQ): RQ1: Is preschool peer group language level associated with receptive vocabulary in third grade, before accounting for subsequent peer contexts? RQ2: When modeled simultaneously, do preschool and primary school peer group language levels exert independent, additive effects? RQ3: Does primary school peer group language level moderate the long-term association between preschool peer composition and later language skills?

Given the research demonstrating long-term associations between early ECEC experiences and later language-related outcomes, we expect a positive association between preschool peer language skills and later vocabulary (RQ1). For RQ2 and RQ3, we take an exploratory approach given limited evidence on peer composition across educational transitions. Nonetheless, we tentatively assume moderating effects, drawing on the sustaining environments framework (Bailey et al., 2017), which specifically addresses how early influences are maintained or attenuated depending on the characteristics of subsequent contexts. In line with the SEH, we hypothesize that higher-skilled primary school peer groups amplify the association between preschool peer composition and later language outcomes.

This study addresses these RQs in the context of transition from ECEC to primary education in Germany. ECEC in Germany is not part of the formal school system and attendance is voluntary, but provided on a universal, non-targeted basis. Provision is mainly centre-based and includes services for children under three as well as for those from age three until school entry around age six, with some institutions combining both age groups. Attendance rates are particularly high

among three- to six-year-olds, exceeding 90% (OECD, 2024). Although commonly referred to as Kindergarten in Germany, we use the term preschool to denote this non-compulsory, pre-primary provision for children aged three to school entry. Preschools typically emphasize child-centered, play-based, and exploratory learning practices that foster holistic development across language, cognitive, and social-emotional domains (Sylva et al., 2015). At about age six, children transition to compulsory primary school, marking a shift toward more formal and academically oriented settings. Unlike preschool enrollment, often involving parental choice, primary school placement usually follows residential zoning and integrates children from multiple ECEC institutions. These institutional, structural, and peer group changes offer a suitable opportunity to study how consecutive peer contexts shape language development.

Method

Data

This paper uses data from the National Educational Panel Study (NEPS; see Blossfeld & Roßbach, 2019). The NEPS is carried out by the Leibniz Institute for Educational Trajectories (LIfBi, Germany) in cooperation with a nationwide network. NEPS employs a multi-cohort sequence design to collect longitudinal data on educational processes and competence development across the life course. Specifically, we draw on data from Starting Cohort 2 – Kindergarten (SC2), which follows children across institutional contexts from early education settings through primary school (NEPS Network, 2024).

Participants in SC2 were recruited in the 2010/2011 school year via a multistage sampling design targeting children in their penultimate preschool year, with ECEC institutions as primary sampling units (Aßmann et al., 2019). The initial sample comprised 2975 children drawn from 279 ECEC centers across 720 groups. At baseline (Wave 1), children had an average age of 4.99 years (SD = 0.37). After transitioning to primary school, most children entered institutions outside the NEPS sampling frame (Steinhauer & Zinn, 2016). To continue data collection in the primary school context, the study recruited a new sample of first-grade students, including classmates of continuing children and a refreshment sample, yielding 6912 children in 374 schools. A subset of 575 children was followed across the transition from preschool to primary school with peer information from both contexts. This subsample allowed us to examine how successive peer groups are associated with children's later vocabulary skills.

Data were collected annually from multiple sources, including child assessments, parent interviews, educator questionnaires, and institutional characteristics. Children's competencies were assessed about every two years in domains such as receptive language, mathematics, and nonverbal cognition. The present study utilized data through Wave 5 (third grade), which provides the last available data on receptive vocabulary.

Analytical sample

The analytical sample consisted of children longitudinally tracked from preschool to primary school. While focal children were limited to this subset, peer group characteristics (i.e., average language skills) were calculated using the full NEPS sample at each wave, including all eligible children within the same institutional unit, referred to as preschool groups and primary school classrooms in the German context. Of the 575 tracked children, 76 were excluded due to insufficient peer information for reliable score estimation (i.e. fewer than two peers with language scores at each timepoint). The final sample comprised 499 children, distributed across 213 preschool groups and 190 subsequent primary school classrooms.

Children in the analytical sample were on average 5 years old (SD = 0.33) at the first assessment in preschool. Of these, 51.4% were female, 13.6% had a family language other than German, and 23.5% of their mothers held a university degree. Socioeconomic status (SES) was represented by the highest parental ISEI (International Socio-Economic Index of Occupational Status; Ganzeboom, 2010), with a mean of 59.46 (SD = 18.93).

To assess potential sample selectivity, we compared children included in the analytical sample to those who dropped out or were excluded. Children retained in the final sample were more likely to come from socioeconomically advantaged families and were less likely to be dual language learners. They also demonstrated higher vocabulary scores at Wave 1, and their peer groups showed higher average language skills. While effect sizes were generally small to moderate, these systematic differences may limit the generalizability of findings to more diverse populations (see Supplementary Materials, Table S1).

Measures

Receptive vocabulary

In the present study, receptive vocabulary was used as the primary language measure for constructing peer group averages, as an individual-level control variable, and as the outcome at third grade. Receptive vocabulary is widely used in developmental research as a well-established, comparable indicator that reflects key aspects of children's language skills (Berendes et al., 2013). It was assessed at three time points – Wave 1 (preschool), Wave 3 (first grade), and Wave 5 (third grade) – using a psychometrically validated German research version of the Peabody Picture Vocabulary Test (PPVT), specifically adapted for the NEPS study (Fischer & Durda, 2020). In this picture-selection task, children heard a spoken target word and were asked to select the image that best matched its meaning from a set of four pictures. In preschool (Wave 1), children were tested individually using 57 items. In primary school (Waves 3 and 5), the tests comprised 66 and 49 items, respectively, and were administered in a group setting. Vocabulary scores were provided as weighted likelihood estimates (WLE) in the NEPS scientific use files. Item selection and test scaling were carried out by the NEPS research team and based on Rasch modeling (for details see Fischer & Durda, 2020; Pohl & Carstensen, 2012). Importantly, item parameters were linked across waves, enabling longitudinal comparability despite differing item sets. The WLE scores demonstrated good reliability across all three assessments (WLE reliability: Wave 1 = 0.89, Wave 3 = 0.87, Wave 5 = 0.84).

Vocabulary scores from Wave 5 (third grade) served as the main outcome measure. Scores from Wave 1 (preschool) and Wave 3 (first grade) functioned both as individual-level control variables and as the basis for calculating group-level peer language skill at each respective time point (see below). Table 1 presents descriptive information for individual vocabulary scores and peer language skills for children included in the analytical sample.

Table 1
Descriptive statistics for vocabulary scores, peer skills, and age at assessment (analytical sample).

Variable	Mean	*SD*	Min	Max	*n*
Age at W1 (years)	5.00	0.33	3.58	5.92	475
Age at W3 (years)	6.97	0.31	5.58	7.67	448
Age at W5 (years)	8.73	0.36	7.42	10.17	405
Vocabulary W1 (WLE)	0.32	0.93	−3.45	2.88	491
Vocabulary W3 (WLE)	1.57	0.76	−0.81	3.71	465
Vocabulary W5 (WLE)	2.66	0.87	0.35	4.96	421
Peer vocabulary W1	0.15	0.58	−2.00	1.44	Level 2 = 213
Peer vocabulary W3	−0.03	0.57	−1.87	1.58	Level 2 = 190

Note. Peer vocabulary scores represent the mean of z-standardized individual vocabulary scores within each group. Reported values reflect the unweighted average across all groups (i.e., each group contributes equally, regardless of size). W = wave; WLE = weighted likelihood estimates.

Group-level variables

Peer language skills were operationalized as the average of all z-standardized individual vocabulary scores within a given group, defined by a unique preschool group identifier at Wave 1 and a unique classroom identifier at Wave 3. Aggregation was conducted prior to multiple imputation and based on the full NEPS sample available at each wave to capture the most comprehensive peer composition. Missingness in the individual vocabulary scores was 4.5% at Wave 1 and 6.5% at Wave 3. To ensure robust group-level estimates, children were only included in the analytical sample if their group-level scores were aggregated from at least three children with valid vocabulary data in both contexts. The average cluster size for calculating peer language skills was 5.59 in preschool and 8.68 in first grade. Each child's own score contributed to their group's average (i.e., self-inclusion). This approach aligns with previous research (e.g., Justice et al., 2011; Lin et al., 2023; Schmerse, 2021) and captures peer language skills as a group-level characteristic. Note that the resulting group-level variables represent the average of the individual z-scores and were not re-standardized at the group level.

Covariates

We included background characteristics commonly associated with both language development and selection into educational contexts. In addition to children's initial language skills at each wave, the models controlled for DLL status, mother's educational background, and child gender, based on information provided by parents. DLL status was coded as a binary variable (1 = DLL, 0 = monolingual), with children identified as DLLs if at least one language other than German was reportedly used by parents in interactions with the child. Maternal highest level of formal education was categorized according to the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012).

For all covariates, values from Wave 1 were used when available. If data were missing at Wave 1, information from subsequent waves was substituted, based on the assumption that these demographic characteristics remain relatively stable over time.

Analytical approach

Peer effects, or compositional effects, reflect the influence of aggregated group-level characteristics on individual outcomes, beyond individuals' own characteristics (Raudenbush & Bryk, 2002). These effects are typically estimated using multilevel regression models, with children (Level 1) nested in groups or classrooms (Level 2). This approach accounts for the clustering in such hierarchical data, allows group-level predictors, and separates individual from contextual influences (Raudenbush & Bryk, 2002). Additionally, the intraclass correlation coefficient (ICC) quantifies the proportion of variance attributable to between-group differences. Given our focus on group composition across settings, it is well suited to address our research questions.

Model specification

We specified a series of multilevel regression models to test the long-term association between preschool peer language skills and later vocabulary, and the additional role of primary school peers. Because children were nested within both preschool groups and subsequent classrooms in varied combinations, the data structure can be considered cross-classified rather than strictly hierarchical (Raudenbush & Bryk, 2002). We initially planned to estimate cross-classified random-intercept models to simultaneously account for both nesting levels. Unconditional cross-classified models revealed moderate between-group variance (ICCs: 0.11 preschool, 0.09 primary school). However, including predictors led to estimation issues, likely due to small effective group sizes and sparse cross-classification in the analytic sample, even though peer skills were based on the full NEPS groups. We therefore adopted a more parsimonious model with random intercepts at the preschool level only, which showed slightly higher ICCs and aligned with our focus on early peer environments. Cross-classified models are reported in the Supplement for transparency (Table S4).

As robustness checks on whether findings held under alternate modeling approaches, we additionally estimated multilevel models with random intercepts at the classroom level instead of the preschool level, and ordinary least squares (OLS) regression with cluster-robust standard errors, providing a simpler way to account for the nested data structure.

To enhance interpretability, all continuous individual-level variables were z-standardized ($M = 0$, $SD = 1$) after imputation, which implies grand-mean centering, allowing coefficients for group-level predictors to be interpreted as contextual effects (Raudenbush & Bryk, 2002). All models controlled for DLL status, gender, and maternal education, with children's individual vocabulary scores at the corresponding time points included to disentangle individual ability from contextual peer effects.

We began with an unconditional (intercept-only) model to estimate the ICC and then specified three successive models to address our research questions. Model 1 tested whether preschool peer language skills predict vocabulary in third grade, without accounting for the influence of later peer contexts. In Model 2, classroom peer skills and individual language skills from first grade were added to assess whether both peer contexts made unique, additive contributions to the outcome when modeled simultaneously. Finally, Model 3 extended this specification by including an interaction term between preschool and classroom peer skills to examine whether the effect of early peer skills was moderated by the subsequent peer environment. To avoid confounding the Level 2 interaction with a corresponding individual-level interaction, we included an interaction term between individual vocabulary scores from Wave 1 and Wave 3 as a statistical control.

All analyses were conducted in R (R Core Team, 2024). Models were estimated using the *lme4* package (Bates et al., 2015) with results pooled across 50 imputed datasets following Rubin's rules using *mitml* (Grund et al., 2023). To obtain more robust 95% confidence intervals, bootstrapping was conducted (1000 draws per model) within each imputed dataset, and percentiles were computed from the combined distribution of all replications (Schomaker & Heumann, 2018).

Missing data treatment

To handle missing data and preserve statistical power, we applied multiple imputation to the full sample of longitudinally tracked children ($n = 575$). Missingness ranged from 0% (peer scores, Wave 1) to 16.2% (Grade 3 vocabulary), with most variables below 6% (Table S2). Missingness was assumed to be at random (MAR), as key covariates theoretically linked to it (e.g., language background, maternal education) were included (Enders, 2022).

Imputation used a substantive model–compatible sequential approach (*mdmb* package; Robitzsch & Lüdtke, 2023) that accounts for the multilevel data structure and interaction terms, reducing potential bias (Grund et al., 2021). We generated 50 datasets, and diagnostics (trace plots, $\hat{R} < 1.02$; Brooks & Gelman, 1998) indicated satisfactory convergence.

Results

Preliminary analyses

Before testing our hypotheses in multilevel regression models, we examined bivariate correlations and multicollinearity diagnostics. Most variables showed moderate to strong correlations in the expected directions (Table S3). Individual vocabulary scores across the three timepoints were strongly correlated, particularly between adjacent waves (e.g., $r = 0.73$ between preschool and first grade), reflecting the expected stability of inter-individual differences in language abilities over time. Peer skills scores at both the preschool group and classroom level also showed significant, albeit more moderate, correlations with later vocabulary in third grade ($r = 0.44$ and 0.39, respectively),

supporting their potential relevance as contextual predictors. All variance inflation factors (VIFs) remained well below common thresholds (Table S3), suggesting that multicollinearity was not a concern (Hair et al., 2019).

We estimate intercept-only two-level models quantifying the proportion of variance attributable to between-group differences. Separate models with either preschool group or school classroom as the grouping variable showed that 17.6% of outcome variance was attributable to preschool group clustering and 15.4% to primary school classroom clustering, indicating a moderate degree of group-level variance in both contexts and supporting the use of multilevel modeling. As outlined in the model specification above, we retained preschool group as the primary clustering level for our main analyses.

The following sections report pooled estimates from 50 imputed datasets, focusing on peer-related predictors relevant to our research questions. Full model results, including bootstrapped 95% confidence intervals, are shown in Table 2. Because the outcome variable was z-standardized, coefficients can be interpreted as standard deviation differences in children's vocabulary.

Long-term effect of preschool peer language skills

Model 1 tested whether peer language skills in preschool predicted later vocabulary in third grade, controlling for children's individual language skills at baseline and relevant covariates. Results indicated a significant positive association between preschool peer language skills and later vocabulary ($b = 0.16$, $SE = 0.08$, $p = .048$). This finding supports the idea of a lasting effect of early peer language environment. However, this model does not account for the influence of subsequent peer contexts.

Additive effects of preschool and primary school peer language skills

In Model 2, we included both preschool and primary school peer language skills – as well as individual language skills at both time points – to examine whether each peer context made a unique contribution to later vocabulary outcomes when statistically controlling for the other. In this additive model, the effect of preschool peer skills was slightly attenuated and did not reach conventional levels of statistical significance ($b = 0.13$, $SE = 0.08$, $p = .082$). Primary school peer skills showed no discernible association with third-grade vocabulary outcomes ($b = -0.01$, $SE = 0.07$, $p = .879$).

Moderating role of subsequent peer context

Model 3 included an interaction term between preschool and primary school peer language skills to investigate whether the effect of preschool peer skills was moderated by the average language skills of the subsequent classroom context. The interaction effect was significant and negative ($b = -0.23$, $SE = 0.09$, $p = .011$), indicating that the influence of preschool peer skills depended on the language skills of the later peer environment, which we probed in follow-up simple slope analyses. Neither the effect of preschool peer skills ($b = 0.11$, $SE = 0.08$, $p = .160$) nor the effect of primary school peers ($b = 0.03$, $SE = 0.07$, $p = .640$) was statistically significant in the interaction model.

To examine the interaction pattern in more detail, we conducted simple slope analyses at different levels of primary school peer language skills (Preacher et al., 2006). Results showed that preschool peer language skills positively predicted third-grade vocabulary outcomes only for children who transitioned to classrooms with relatively low primary school peer skills (−1 SD: $b = 0.22$, $p = .008$). No significant associations were found at average levels of primary school peer skills ($b = 0.10$, $p = .193$) or in classrooms with relatively high peer skill levels (+1 SD: $b = -0.02$, $p = .806$).

A Johnson-Neyman analysis (Preacher et al., 2006) indicated that the effect of preschool peer language skills became statistically significant when primary peer language skills were below −0.18 (Fig. 1), what corresponds to classrooms with moderately below-average peer competence. Approximately 33.7% of children in the analytical sample were in primary school classrooms with a peer skill level below this value, suggesting that the identified moderation effect is relevant for a substantial portion of the sample.

Robustness checks and additional analyses

Robustness checks with random intercepts at the primary classroom level yielded highly consistent effects (Table S5), as did OLS regression models with cluster-robust standard errors at the preschool group level (Table S6), which showed only minor deviations in standard errors.

We further conducted supplementary analyses controlling for aggregated socioeconomic composition (classroom-level maternal education) to examine whether peer language effects reflected broader classroom socioeconomic characteristics (see Supplementary Materials S4.1). Results showed that the main effect of preschool peer language skills was substantially attenuated across models (see Table S9). The effect of primary school peer language skills remained negligible, while the interaction between early and later peer language skills remained statistically significant and comparable in magnitude.

Discussion

Using data from a German longitudinal panel that followed children from preschool to primary school, this study examined whether early peer group composition exerts lasting effects on children's language

Table 2
Fixed effects from multilevel regression models predicting third-grade vocabulary.

	Model 1				Model 2				Model 3			
	b	*SE*	*p*	95% CI	*b*	*SE*	*p*	95% CI	*b*	*SE*	*p*	95% CI
(Intercept)	−0.06	0.06	0.301	[−0.16, 0.04]	−0.04	0.05	0.369	[−0.14, 0.05]	−0.03	0.05	0.592	[−0.13, 0.07]
Vocabulary W1 (age 5)	**0.56**	0.04	< 0.001	[0.48, 0.64]	**0.18**	0.05	0.001	[0.08, 0.27]	**0.18**	0.05	< 0.001	[0.08,0.28]
Vocabulary W3 (age 7)					**0.58**	0.05	< 0.001	[0.48, 0.67]	**0.58**	0.05	< 0.001	[0.48, 0.67]
Gender	0.08	0.07	0.242	[−0.05, 0.22]	0.06	0.06	0.360	[−0.06, 0.18]	0.05	0.06	0.425	[−0.07, 0.17]
Maternal education	0.07	0.04	0.082	[−0.00, 0.15]	−0.00	0.04	0.910	[−0.07, 0.06]	−0.00	0.04	0.906	[−0.07, 0.06]
DLL	**−0.28**	0.11	0.013	[−0.49, −0.06]	**−0.28**	0.10	0.005	[−0.47, −0.09]	**−0.27**	0.10	0.005	[−0.47, −0.08]
Peers Skills												
Peer-Vocabulary W1 (age 5)	**0.16**	0.08	0.048	[0.01, 0.31]	0.13	0.08	0.082	[−0.01, 0.28]	0.11	0.08	0.160	[−0.03, 0.25]
Peer-Vocabulary W3 (age 7)					−0.01	0.07	0.879	[−0.15, 0.12]	0.03	0.07	0.640	[−0.10, 0.17]
Interaction Terms												
Voc. W1*Voc. W3									0.03	0.03	0.187	[−0.02, 0.08]
Peer-Voc. W1*Peer-Voc. W3									**−0.23**	0.09	0.011	[−0.40, −0.06]

Note. All models included random intercepts at the preschool group level. Significant estimates ($p < .05$) are shown in bold. CI = 95% percentile bootstrap interval pooled across 50 imputed datasets (1000 resamples per model). W = wave; DLL = dual language learner; Voc = vocabulary.

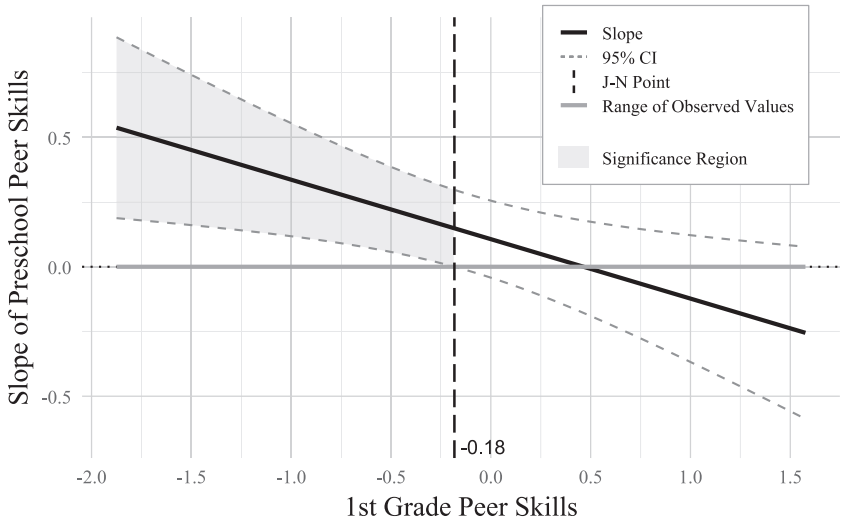

Fig. 1. Preschool peer effect on 3rd grade vocabulary moderated by 1st grade peer skills.
Note. CI = confidence interval; J-N = Johnson-Neyman.

development and explored the role of the new peer environment after school entry in shaping such association. We identified a modest but meaningful long-term link between preschool peer language skills and receptive vocabulary in third grade. The interplay between consecutive peer environments revealed that primary school peer composition did not show an independent additive effect but instead moderated the preschool peer effect, which was more pronounced when later peer groups had lower average language skills.

Preschool peer language skills as long-term predictor

Consistent with developmental perspectives that emphasize the formative nature of early experiences (Shonkoff & Phillips, 2000), we found that children from preschool groups with higher average language skills showed higher receptive vocabulary in third grade, even after accounting for child and family characteristics. Importantly, this model captures the overall association of classroom language composition with later outcomes prior to accounting for other aspects of classroom such as socioeconomic composition and subsequent developmental contexts. This relation was notably attenuated when aggregated maternal education was included in supplementary analyses, suggesting that language and socioeconomic composition are closely intertwined at the classroom level. Accordingly, the observed effect likely reflects broader compositional characteristics of early educational settings rather than language composition in isolation, while still pointing to lasting links between early classroom contexts and later vocabulary development.

Beyond most prior research on preschool peer composition, which has emphasized short-term outcomes (Foster et al., 2020; Kohl et al., 2022; Mashburn et al., 2009), our study offers a longer-term perspective. Schmerse (2021), using growth curve modeling, reported associations with vocabulary growth up to first grade. Our findings extend this work by suggesting that early classroom compositional contexts may be associated with language development even further into middle childhood. In addition, they also complement research on the lasting impact of ECEC experiences, which has primarily focused on quality measures or teacher input (Dickinson & Porche, 2011; Ulferts et al., 2019), by highlighting peer composition as another contextual factor of potential lasting importance for children's language development.

While the mechanisms underlying these long-term associations remain to be explored, our results suggest that peer composition in early childhood may have measurable relevance several years later. Yet such effects do not occur in isolation. Children's later environments, particularly peer groups in primary school, may either reinforce or diminish early influences.

Joint effects of preschool and primary school peer language skills

Although prior research has documented associations between peer composition and language development in both preschool and primary school settings (Mashburn et al., 2009; Quinn et al., 2018), these contexts have rarely been examined together. By modeling both simultaneously, we tested whether later peer groups add explanatory value or alter the strength of preschool peer effects on later vocabulary.

Additive effects of successive peer environments

When both peer contexts were included in the model, the effect of preschool peer language composition was attenuated and no longer statistically significant. Although the association with later vocabulary remained positive, it was further reduced when classroom socioeconomic composition was included. Primary school peer language composition showed no independent association with third grade vocabulary, despite its temporal proximity to the outcome. Instead, children's language competence at school entry emerged as the strongest predictor, suggesting that much of the variance may already be explained by individual skills. These results suggest that, once earlier peer exposure and individual language skills are accounted for, the unique contribution of later peer context appears limited. This may partly reflect developmental shifts in peer sensitivity across educational stages. At the same time, the structure of the data may have constrained our ability to disentangle both contextual effects, as cross-classification between preschool and primary school settings was sparse.

To further explore the observed pattern, we estimated an additional model including only primary school language composition. Results likewise showed no significant association of primary school peer skills with later vocabulary (Table S10), reinforcing the interpretation that the later peer environment did not account for variation in vocabulary outcomes—even without controls for prior exposure.

Moreover, primary school peers represent a temporally subsequent contextual exposure that is correlated with earlier environments. Including both contexts in the same model may therefore yield a more conservative estimate of the preschool peer association, insofar as later peer context captures continuity or overlap in children's peer experiences across settings. However, the absence of an independent association between primary school peer composition and later vocabulary provides little support for the interpretation that later peer context explain the observed preschool association. Importantly, our analyses

were not designed to disentangle indirect pathways or formally test causal mechanisms linking successive peer contexts.

Our findings are in line with research on other contextual factors and domains across developmental stages, where later environments often contribute little when considered alongside early experiences (Anders et al., 2013; Ansari & Pianta, 2018b; Hansen & Broekhuizen, 2021). For instance, Anders et al. (2013) reported that preschool classroom quality predicted numeracy skills in first grade, whereas primary school quality had no additional effect. Yet, other studies suggest that early and later contexts can exert independent effects (Ansari & Pianta, 2018b; Carr et al., 2019; Lehrl et al., 2016). Carr et al. (2019), for example, documented additive effects of instructional support across pre-K and kindergarten specifically for language and literacy skills, showing that both stages can make distinct contributions to children's verbal development. This mixed evidence across studies could be related to variability in domain, type of contextual factor, and developmental timing of measurement and exposure.

Although primary school peers played only a minor role for third-grade vocabulary in our study after adjusting for early peer experiences and individual competencies, the absence of additive effects does not rule out the possibility that later peer contexts may moderate the effects of early peer experiences.

Moderation effect of primary school peer groups

Informed by the SEH (Bailey et al., 2017), we hypothesized that preschool peer effects on later language skills would be amplified when children entered primary school peer groups with higher average language skills. Contrary to this assumption, the association between preschool peer language skills and third-grade receptive vocabulary was only evident for children whose later peer group had lower average language skills, whereas no preschool peer effect was detectable in average- or high-scoring peer environments. The interaction between preschool and primary school peer language composition remained statistically significant and comparable in magnitude after accounting for socioeconomic classroom composition. The conditional effects were more concentrated at the lower end of the primary school peer language distribution. However, this indicates that the central pattern of results – the systematic interplay between early and later peer language contexts – is robust to broader compositional differences between classrooms.,

This moderating pattern supports a compensatory interpretation in which early peer experiences may become particularly relevant in less supportive later peer groups. In such contexts, earlier exposure to skilled peers may build adaptive capacities that buffer against weaker input. At the same time, the lack of detectable preschool effects in higher-skilled later peer environments could reflect catch-up processes among children from lower-skilled preschool groups, which reduce early peer-related differences (Abenavoli, 2019; Magnuson et al., 2007). Additionally, for children already exposed to high-skilled preschool peers, additional peer input in primary school may offer limited gains due to ceiling effects, where returns of new input diminish once foundational competencies are already strong.

From the perspective of the sustaining environments framework our results are unexpected but parallel prior evidence showing that peer effects tend to be stronger under less favorable conditions. At the individual level, children with lower skills tend to benefit more from skilled peers (e.g., Hürlimann et al., 2025; Justice et al., 2011; Quinn et al., 2018). However, these studies focus on conditionality within a single developmental context (i.e., variation in individual responsiveness), whereas the present study examines how early peer effects are shaped by subsequent peer contexts over time. Whether individual characteristics further moderate these cross-context dynamics remains an open question for future research.

Beyond within-context evidence, similar patterns have also been observed in research examining effects of subsequent educational contexts. Some prior studies have reported sustained benefits of early childhood education even when later educational environments were less favorable. For instance, Bierman et al. (2014) and Magnuson et al. (2007) found that early educational advantages in reading or social competence persisted in primary school settings with larger class sizes, lower instructional quality, or low school-level achievement. Similarly, the Effective Pre-school and Primary Education study (EPPE; Sylva et al., 2008) demonstrated that high-quality preschool experiences could provide advantages for children who later attended less academically effective primary schools, while also showing that the strongest gains occurred when both stages were of high quality.

In contrast, other studies align with the SEH, finding stronger long-term benefits when later environments were more supportive (Ansari & Pianta, 2018a, 2018b; Pearman et al., 2020; Swain et al., 2015). For example, Ansari and Pianta (2018b) observed that long-term benefits of early child care quality for language and literacy were more pronounced when followed by high-quality elementary classrooms. However, these effects were absent in third grade and only emerged by fifth and ninth grade, highlighting that timing may be critical. Overall, the broader SEH literature shows considerable variability in moderation patterns that likely reflects differences in domain, contextual features, and timing (Bailey et al., 2020). Some studies even suggest that sustaining early gains may require the combination of multiple high-quality factors (Pearman et al., 2020). Likewise, studies addressing peer composition as a sustaining factor have also produced mixed results, ranging from sustained effects under experimental conditions (List & Uchida, 2024) to limited or inconsistent effects (Botvin et al., 2024; Burchinal et al., 2023; Shea et al., 2025).

Taken together, our study extends this evidence by suggesting a compensatory pattern for peer composition, a factor rarely examined across educational stages. Specifically, the association of preschool peer language skills with vocabulary in third grade remains evident under lower levels of primary school peer language skills, pointing to a possible alternative pathway through which early experiences may have lasting effects - not through continuity and amplification, but potentially through providing resources that become particularly valuable under less supportive later conditions.

Although the observed effects are modest, they are notable given the longitudinal time span and the fact that they reflect naturally occurring variation rather than targeted interventions. The effect sizes are comparable to those reported for other contextual predictors of children's language development in early childhood research (Keys et al., 2013; Schmerse et al., 2018; Ulferts et al., 2019) and align with broader evidence that modest effects can be practically important in educational settings (Kraft, 2020), particularly for developmental outcomes shaped by multiple small, cumulative influences (Götz et al., 2022). This suggests that peer composition constitutes a relevant contextual dimension within early education, alongside more commonly studied structural and process quality features.

Future research should examine under what conditions such compensatory effects emerge, whether they generalize to other developmental outcomes, and how other classroom-level factors (e.g., instructional quality or teacher practices) might interact with peer composition to shape long-term trajectories.

Limitations

By systematically examining peer group effects across institutional transitions, this study addresses an important gap in literature. Nevertheless, several limitations should be considered when interpreting the results. First, as with all observational studies, no causal inferences can be drawn, as selection into both preschool and primary school remains a concern. While we adjusted for key child and family characteristics known to affect both educational placement and language development, unmeasured confounding cannot be ruled out. Including children's early language skills may partially account for some prior developmental and contextual influences but is unlikely to eliminate all sources of bias.

Second, our peer composition measure relied on average language

skills of participating children within each classroom, who typically represented only a subset of total class enrollment. As a result, the assessed peer environment may not fully reflect the skills of all classmates or the peers with whom a child interacted most often. This limitation could reduce both the representativeness of our measure and the precision of estimated peer effects.

Third, our focus on average peer language skills does not address mechanisms through which early peer effects may operate. It remains unclear whether peer composition shapes language development primarily through direct exposure to richer language input and increased opportunities for verbal interaction with skilled peers, or indirectly via classroom-level factors such as teacher practices, instructional quality, or classroom organization (Mashburn et al., 2009; Shea et al., 2025). Future research could disentangle these pathways by combining detailed measures of peer interaction and network structure (Chen et al., 2020) with assessments of classroom and teacher factors across multiple educational stages. Such work would also allow examining whether these mechanisms play similar or distinct roles in early versus later peer contexts.

Finally, systematic differences between our analytical sample and excluded participants, encompassing higher socioeconomic status, initial language skills, and peer language competence, may limit the generalizability of findings to more diverse populations. Additionally, the specific structure of German preschools and primary schools may limit generalizability to other educational contexts.

Conclusion

Early peer relations are often considered fleeting. Yet our findings reveal that preschool peer composition, as an indicator of broader classroom characteristics, showed modest but lasting associations with children's vocabulary development through third grade. Importantly, these associations appear to function in a potentially compensatory manner, becoming most evident when children subsequently join less supportive peer group contexts.

These results suggest that early peer environments may interact with later contexts in ways that are relevant for practice and policy. While replication is needed, the findings point to the potential value of considering peer composition within existing practices of classroom organization and grouping in early educational settings. In particular, fostering linguistically rich preschool peer environments and opportunities for peer interaction may support children's language development well beyond preschool years, particularly for children at risk of transitioning into less supportive later peer contexts.

While the present study provides initial evidence of the joint effects of preschool and primary school peers on later language outcomes, further research is needed to replicate these findings across different educational systems and populations, to clarify the mechanisms underlying these associations, and to examine whether and how compositional features can be leveraged to support children's language development in practice.

CRediT authorship contribution statement

Franziska Hürlimann: Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Oliver Lüdtke:** Writing – review & editing, Methodology. **Daniel Schmerse:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

We have no known conflict of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appdev.2026.101973.

Data availability

NEPS data are available as scientific use files with a data use agreement from the Research Data Center at the Leibniz Institute for Educational Trajectories (FDZ-LIfBi).

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