

# Language Ability in the Development of Externalizing Behavior Problems in Childhood

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Poorer language ability has been shown to predict the development of externalizing behavior problems such as aggression and conduct problems. However, the developmental process that links poorer language ability to externalizing problems is unclear. The present study examined (a) whether within-child changes in language ability predict within-child changes in externalizing problems, (b) whether social skills are a potential mechanism that explains the association between language ability and externalizing problems, and (c) whether there are sex-related differences in the association between language ability and externalizing problems. The present study examined these questions in children ( $N = 1,364$ ) followed annually from 4 to 10 years of age. Language ability was assessed by a measure of receptive language (i.e., vocabulary). Externalizing problems were rated by mothers and teachers. Social skills were rated by mothers, fathers, and teachers. Findings showed that within-child changes in language ability predicted within-child changes in externalizing problems, even controlling for the family's income-to-needs ratio. We found that social skills partially mediated the association between poorer language ability and later externalizing problems, but this was limited to a between-person effect. There was not strong evidence of sex-related differences in the association. Findings suggest that language ability may play a role in the development of externalizing problems for boys and girls, and that social skills may be a mechanism that partially explains how poorer language ability leads to the development of externalizing problems. Or, alternatively, language ability, social skills, and externalizing problems may partially share common causes.

## *Educational Impact and Implications Statement*

Poorer language ability in children has been shown to predict the development of externalizing behavior problems such as aggression and conduct problems, but the reasons for this are not known. In a sample of 4- to 10-year-old children, language ability predicted their changes in externalizing problems. Poorer social skills partially explained why children with poorer language ability tended to develop more externalizing problems. The association between poorer language ability and more externalizing problems was similar for boys and girls. Findings suggest that poorer language ability may play a role in the development of externalizing problems for boys and girls, and that poorer social skills may be a mechanism that partially explains how poorer language ability leads to the development of externalizing problems. However, it is also possible that language ability, social skills, and externalizing problems partially share common causes.


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Externalizing behavior problems, which consist of acting-out behaviors such as aggression, defiance, and conduct problems, are frequent, costly, and burdensome in children. The worldwide prev-

alence of externalizing disorders (e.g., conduct disorder and oppositional defiant disorder) in childhood is estimated to be 5.7%, or 113 million children (Polanczyk, Salum, Sugaya, Caye, &

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Rohde, 2015). Externalizing problems result in considerable costs to families, health care systems, and schools (Knapp, Scott, & Davies, 1999; Romeo, Knapp, & Scott, 2006). Not only might externalizing problems impair a child's own learning and achievement in the classroom (Hinshaw, 1992), they are also disruptive in the classroom and could impair peers' learning (Seidman, 2005). Moreover, childhood externalizing problems can have impairing consequences for a child's later development. Although people tend to show some fluctuation in level of externalizing problems across development, individual differences in externalizing problems tend to be relatively stable from childhood to adulthood (Fergusson, 1998; Olweus, 1979). Moreover, externalizing problems in childhood predict severe outcomes in adulthood including substance use and criminality (Petersen, Bates, Dodge, Lansford, & Pettit, 2015). Thus, it is crucial to understand factors that lead to the development of externalizing problems in childhood.

### Poorer Language Ability in the Development of Externalizing Problems

Poorer language ability is a key potential risk factor in the development of externalizing problems. Language ability refers to a broad range of language-related skills, including expressive and receptive language skills. Considerable evidence has established that poorer language ability is concurrently associated with externalizing problems (e.g., for reviews and meta-analyses, see Chow & Wehby, 2018; Yew & O'Kearney, 2013). There is also evidence that language ability predicts the development of later externalizing problems (e.g., for reviews and meta-analyses, see Chow, Ekholm, & Coleman, 2018; Chow & Wehby, 2018). Prior longitudinal studies of the association between language ability and externalizing problems have primarily examined whether children's levels of language ability at a given time point (T1) are associated with their levels of externalizing problems at a later time point (T2), with considerably fewer studies including controls for their prior levels of externalizing problems at T1 (i.e., autoregressive controls; e.g., Petersen et al., 2013; Spilt, Koomen, & Harrison, 2015). Controlling for prior levels is important because the association of language ability at T1 with externalizing problems at T2 could reflect the opposite direction of effect from externalizing problems to language ability (i.e., the lagged association could owe to stability in externalizing problems from T1 to T2). Studies that test whether language ability predicts later externalizing problems controlling for prior levels of externalizing problems examine whether language ability predicts *change* in externalizing problems, a stronger test of developmental process.

We are aware of only one other study that has examined the association between language ability and later behavior problems in the NICHD Study of Early Child Care and Youth Development (SECCYD; the sample in the present study). In a path analysis using the SECCYD sample, Russell and colleagues (2016) found that less secure mother-child attachment and less maternal sensitivity at 36 months predicted poorer language ability (as measured by the Preschool Language Scale, combining expressive and receptive language) at 54 months of age, which in turn predicted more oppositional behavior in first grade as reported by teachers. However, the study did not control for prior levels of behavior problems in the association, so it could not examine whether language ability predicted *change* in behavior problems. Further-

more, the study did not examine potential mediators of the association between language ability and externalizing problems. Including autoregressive controls and examining potential mediators is important to advance understanding of the developmental process linking language ability to externalizing problems.

Although some studies have found that behavior problems are associated with later language difficulties (e.g., Haak, Downer, & Reeve, 2012), studies that have simultaneously examined both directions of effect have typically found stronger associations from language to later externalizing behavior problems than the reverse (e.g., Petersen et al., 2013; Wang, Aarø, & Ystrom, 2018; but see Bornstein, Hahn, & Suwalsky, 2013). For example, Petersen and colleagues (2013) found that language ability predicted later externalizing problems, whereas externalizing problems did not predict later language ability. The magnitude of the association between language ability and later externalizing problems was approximately 2–4 times stronger than the reverse (though effect sizes were modest). Studies have also observed that language may have specific effects on aggression-related externalizing problems compared with other behavior problems including attention-deficit/hyperactivity disorder (Wang et al., 2018).

### Possible Mechanisms

Several mechanisms have been proposed for how poorer language ability may lead to the development of externalizing problems. First, researchers have argued that language allows children to communicate their needs so their needs are met (Keenan & Shaw, 1997, 2003). Poor language skills might prevent children from meeting their needs, and if they become frustrated that their goals are not met, children with poorer language skills may resort to other methods like aggression to achieve their goals. Second, researchers have suggested that language may serve a self-regulatory function. For instance, Vygotsky (1962) and Luria (1961) theorized that children use language to guide their behavior in the form of private (self-directed) speech during challenging tasks. Children with better language abilities may be better able to use language for self-control of their behavior (Valloton & Ayoub, 2011). Third, it has been hypothesized that poorer language skills may lead children to be rejected by peers (Menting, van Lier, & Koot, 2011), and peer rejection is a strong risk factor for externalizing problems (Dodge et al., 2003). Menting and colleagues (2011) argued that children with poorer language ability (especially vocabulary) may be more likely to be rejected by their peers for several reasons. First, they may have difficulty labeling and communicating their emotions that lead to difficulties in emotion regulation (e.g., Roben, Cole, & Armstrong, 2013). Second, they may have difficulty recognizing and understanding others' emotions leading to difficulties interpreting social interactions (Salmon, O'Kearney, Reese, & Fortune, 2016). Thus, poorer language skills might lead children to have poorer social skills, leading to peer rejection, which puts children at risk for developing externalizing problems. In sum, language has been hypothesized to serve various roles in the development of externalizing problems.

Despite the multiple hypothesized mechanisms of the role of language ability in the development of externalizing problems, we are aware of only three studies that have examined mediators of the association between language ability and later behavior prob-

lems. Petersen and colleagues (2015) followed children from 30 to 42 months of age, and found that self-regulation partially mediated the association between language ability and later inattentive-hyperactive behavior problems. Findings that language may serve a self-regulatory role in the development of behavior problems are consistent with evidence that children's better language skills are associated with better anger regulation strategies, and in turn, less anger (Roben et al., 2013). Westrupp and colleagues (2019) found that literacy at ages 8–9 years (but not peer problems) partially mediated the association between change in receptive language skills (i.e., vocabulary) from ages 4–9 years and externalizing problems at ages 8–9 years.

In addition, Menting and colleagues (2011) observed that children's change in peer rejection scores (based on peer nominations) from Grades 1 to 4 mediated the association between receptive language skills (i.e., vocabulary) at Grade 2 and changes in externalizing problems from kindergarten to Grade 4. They also observed stronger associations between peer rejection and later externalizing problems for boys than girls. Findings by Menting and colleagues provide important suggestions that peer rejection may mediate the association between language ability and behavior problems, especially for boys, but the study also had limitations. First, language skills were measured at only one time point, which prevented the authors from examining the association between language ability and externalizing problems within the individual, which we describe later. Second, change in the mediator (peer rejection: Grades 1–4) and outcome (externalizing problems: kindergarten to Grade 4), in part, temporally preceded the predictor (language ability: Grade 2). Thus, the directionality of the mediational association is unclear. For instance, it could be that peer rejection led children to develop poorer language skills rather than the reverse. Rejection by their peers may lead children to be more socially isolated or to lose motivation to attend their classes or achieve in school. Thus, peer rejection may impair the child's language learning opportunities. Given these limitations and the general paucity of studies examining mediators of the association between language and externalizing problems, the roles that language ability plays in the development of externalizing problems are unclear.

If peer rejection mediates the effect of poorer language ability on the development of externalizing problems, it could be important to identify more malleable intermediate processes that underlie this developmental pathway. Social skills are one possible intermediate process that could be more directly malleable than peer rejection at the individual-level for a given child client. For instance, it could be easier to directly target the client's social skills compared with targeting a client's many peers in intervention to ensure they accept the client. Improving a child's social skills may make it less likely that they are rejected by peers. The most effective interventions for peer rejection emphasize social skills training (Bierman, 2004). A mega-analysis has shown that social skills training is effective for children with emotional and behavioral disorders (Cook et al., 2008). Although universal school-based programs for improving social competence and preventing bullying may be helpful, they are not considered replacements for social skills training with indicated peer-rejected children (Bierman, 2004). Thus, the present study examines whether social skills are a

potential mechanism that explains how poorer language ability leads to externalizing problems.

### Potential Sex-Related Differences

Considerable research has established sex-related differences in language ability and externalizing problems, with boys showing lower language ability and more externalizing problems, on average, compared with girls (Keenan & Shaw, 1997). Given the robust mean differences between boys and girls in language ability and externalizing problems, it is important to determine whether there are sex-related differences in the association between language ability and externalizing problems. If the association between language ability and externalizing problems is stronger for boys compared with girls (or vice versa), it could provide evidence of different developmental pathways to girls' and boys' development of externalizing problems. However, prior findings have been inconsistent. Some studies have found that the association between language ability and externalizing problems is stronger for girls (Monopoli & Kingston, 2012), others have found a stronger association among boys (Brownlie et al., 2004), and yet other studies have found no difference in the strength of the association between boys and girls (Petersen et al., 2013). Thus, more research is needed to clarify the nature of the association between language ability and externalizing problems for boys and girls. The sex-related differences in the prevalence of externalizing problems emerge around age 4 (Keenan & Shaw, 1997). Therefore, the present study, which examines the development of language ability and externalizing problems from ages 4–10 years, presents an important opportunity to better understand whether there are sex-related differences in the association between language ability and the development of externalizing problems.

### Design Features to Improve Understanding of Developmental Process

Repeated-measures designs importantly allow examining the association within the individual. Examining the association within the individual provides a stronger test of developmental process because it uses the individual as their own control and removes all time-invariant confounds (Curran & Bauer, 2011; Duckworth, Tsukayama, & May, 2010). Different associations can exist at the group level (between-person) and at the individual level (within-person), and mistakenly attributing a between-person association to a within-person association is known as the ecological fallacy (Curran & Bauer, 2011). Thus, it is crucial to test the extent to which language ability is associated with externalizing problems within the individual. A within-person association can be examined using a person-mean centering approach, which involves centering a person's scores so that their score at each time point reflects their time-specific deviation from their own mean (Curran & Bauer, 2011). When examining a within-individual association using person-mean centering, peoples' time-specific deviations on the predictor are examined in relation to their time-specific deviations on the outcome. Thus, the approach examines whether within-person changes in the predictor are associated with within-person changes in the outcome. We are aware of only one study that examined the association between language and externalizing problems *within* the individual (Wang et al., 2018). Wang and

colleagues examined the within-child association between mother-reported language delay and externalizing problems in preschoolers, while controlling for between-child differences in language delay and externalizing problems. The authors found that within-child differences in language delay were associated concurrently with within-child differences in aggression but not inattention. In their study, both language delay and externalizing problems were assessed by a common method (questionnaire) and informant (mother), and language delay was dichotomized. However, individual differences across the full spectrum of language ability could have meaningful implications for prosocial behavior. The present study examined the within-child association between language ability and externalizing problems using an objective, performance-based measure of language ability that allowed us to examine the full range of language ability, and used a person-mean centering approach.

### The Present Study

The present study sought to advance understanding of the developmental process linking language ability and externalizing problems by investigating three questions in a longitudinal sample of children from 4–10 years of age. First, we examined whether within-child changes in language ability predict concomitant within-child changes in externalizing problems (Q1). To answer this question, we used growth curve models of externalizing problems with language ability as a person-mean-centered predictor to disaggregate within-person effects from between-person effects in the association between language ability and externalizing problems. Second, we examined whether social skills are a potential mechanism that explains the association between language ability and externalizing problems (Q2). To answer this question, we used cross-lagged models that controlled for temporal stability of each construct to determine whether language ability predicts later change in externalizing problems via change in social skills (i.e., indirect effect or mediation). Third, given inconsistent evidence of sex-related differences in the association between language ability and externalizing problems, we examined as a secondary, exploratory question whether there are sex-related differences in the association between language ability and externalizing problems (Q1B, Q2B).

### Method

#### Participants

Children ( $N = 1,364$ ; 659 girls; 611 first born) and their families were recruited for the National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development (SECCYD) in 1991 from 31 hospitals near one of 10 locations in the United States: Little Rock, AR; Irvine, CA; Lawrence and Topeka, KS; Boston, MA; Charlottesville, VA; Morganton and Hickory, NC; Seattle, WA; and Madison, WI. Infants were recruited at birth and were followed until they were 15 years old. The present study considered the association between language ability and externalizing problems in children followed annually from 4 to 10 years of age (i.e., 54 months of age to fifth grade), when measures of language ability and behavior problems were both available. Although the sample is not nationally repre-

sentative, it reflects a diverse sample. In terms of the child's ethnicity, the sample was 80.4% White, 12.9% Black, 1.6% Asian American, 0.4% American Indian, and 4.7% of other ethnicity. Of children, 6.1% were Hispanic. At intake, mothers ranged from 18 to 46 years of age ( $M = 28.11$ ,  $SD = 5.63$ ). Households had 4.27 people on average ( $SD = 1.17$ ), and 77% had fathers living in the home. The study was approved by the institutional review boards of all relevant institutions. For more information about the study and sampling procedures, see the NICHD Early Child Care Research Network (2005).

The extent of missingness for model variables is shown in Table S1 in the online supplemental materials. We observed some missingness that was related to measured variables. Compared with girls, boys had more missing scores for language ability,  $t(1,361.70) = -2.72$ ,  $p = .007$ , and both mother-,  $t(1,361.10) = -2.38$ ,  $p = .017$ , and teacher-,  $t(1,359.40) = -2.17$ ,  $p = .030$  reported externalizing problems. Families with a lower income-to-needs ratio at 54 months also had more missing scores for mother-,  $t(1,071) = .06$ ,  $p = .035$ , and teacher-,  $t(1,071) = .14$ ,  $p < .001$ , reported externalizing problems, but they did not show more missing scores for language ability,  $t(1,071) = .03$ ,  $p = .257$ . Thus, we included the child's sex and the family's income-to-needs ratio as covariates in the final models.

#### Measures

A data dictionary of the study variables is published at <https://osf.io/dyqt5/>.

**Language ability.** Consistent with prior studies examining language abilities in relation to externalizing problems, we used a receptive language measure of vocabulary as our measure of language ability. We used the Picture Vocabulary subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R; Woodcock, Johnson, & Mather, 1990). The Picture Vocabulary subtest assesses the child's ability to name familiar and unfamiliar pictured objects, and has shown a median internal consistency reliability of  $\alpha = .86$  in prior work (Woodcock, 1990). We use the label *language ability* for several reasons. First, it is consistent with prior research using similar measures (e.g., Monopoli & Kingston, 2012; Petersen et al., 2013). Second, different aspects of language ability typically load onto one general language ability factor, especially before adolescence (Tomblin & Zhang, 2006). Third, research has not theoretically or empirically delineated how different aspects of language ability would be related differently to externalizing problems, and associations have been similar across different aspects of language ability (e.g., Petersen et al., 2013). Language ability was assessed every two years from 4 to 10 years of age. We used raw scores of language ability because age-normed scores prevent detecting absolute change and researchers are advised against using age-normed scores (e.g., standard scores) in longitudinal studies (Moeller, 2015; Willett, Singer, & Martin, 1998).

**Externalizing behavior problems.** Externalizing problems were rated by mothers on the Child Behavior Checklist 4–18 (CBCL; 34 items; Achenbach, 1991a), and by teachers on the Teacher's Report Form (TRF; 34 items; Achenbach, 1991b). Externalizing problems were rated annually by mothers and teachers from 4 to 10 years of age (except mothers did not rate their child's externalizing problems at age 7). At age 4, the TRF was completed either by a preschool teacher or other caregiver (e.g., daycare



provider). The Externalizing scale on each measure consists of two subscales: Delinquent Behavior and Aggressive Behavior. Items were rated as *not true*, *somewhat or sometimes true*, or *very true or often true*, scored 0, 1, and 2, respectively. Mean internal consistency across ages in this sample was  $\alpha = .89$  for mothers' ratings (range: .88 to .91) and  $\alpha = .95$  for teachers' ratings (range: .93 to .95). The Achenbach scales are empirically derived, widely used, and show strong reliability (internal consistency, test-retest reliability, and interrater reliability) and validity (content, construct, and criterion-related validity; Sattler, 2014).

Because of the wide age range spanned in the present study, we aimed to ensure we were measuring the same externalizing problems construct on the same scale across time. This is an important consideration because externalizing problems show changes in their manifestation across development, from overt to covert forms of behavior (i.e., heterotypic continuity; Chen & Jaffee, 2015; Petersen, Bates, Dodge, et al., 2015). Even though the same measures were used across all ages, measures can change in meaning across lengthy developmental spans (Petersen, Lindhiem, et al., 2018). To ensure we were measuring the same externalizing problems construct on the same scale across ages, we used an item response theory (IRT) approach to vertical scaling, consistent with recommendations from previous research (described later; Kolen & Brennan, 2014; Petersen, Lindhiem, et al., 2018). Vertically scaled IRT-derived factor scores were used as the child's level of externalizing problems, with higher levels corresponding to greater externalizing problems. Factor scores of externalizing problems at each age were scaled in reference to the factor scores of externalizing problems at age 4. Factor scores of externalizing problems at age 4 had a mean of zero and a standard deviation near one.

**Social skills.** Children's social skills were rated by mothers, fathers, and teachers on the Social Skills Questionnaire from the Social Skills Rating System (SSRS; Gresham & Elliott, 1990). Mothers, fathers, and teachers completed the SSRS annually (except mothers at age 7, fathers at ages 4, 5, and 7, and teachers at age 4). The Social Skills Questionnaire includes 38 items assessing the frequency of children's cooperation, assertion, responsibility, and self-control behaviors on a 3-point (0–2) scale. Correlations across raters within year ranged from .21 to .52 ( $M = .36$ ,  $ps < .001$ ), depending on the year measured. The modest interrater correlations are consistent with prior work examining parents' and teachers' ratings on the SSRS (Gresham, Elliott, Cook, Vance, & Kettler, 2010), and are consistent with modest interrater agreement of other constructs (Achenbach, McConaughy, & Howell, 1987). The modest interrater agreement suggests the importance of incorporating multiple perspectives of the child's behavior. Consistent with prior research in the NICHD SECCYD (Laible, Carlo, Davis, & Karahuta, 2016), we combined SSRS scores across raters. Scores were first summed across items within rater, and then averaged across raters (mother, father, teacher), with higher scores reflecting higher social skills. As a sensitivity test, we also examined models separately for each rater. Mean internal consistency across ages in this sample was  $\alpha = .89$  for mothers' ratings (range: .86 to .91),  $\alpha = .89$  for fathers' ratings (range: .86 to .91), and  $\alpha = .95$  for teachers' ratings (range: .94 to .95).

**Covariates.** To control for potential confounds in the association between language ability and externalizing problems, we included model covariates, including the child's sex and the fam-

ily's income-to-needs ratio (Dearing, McCartney, & Taylor, 2006). The family's income-to-needs ratio was a time-varying covariate.

## Statistical Analysis

**Vertical scaling of externalizing problems.** We used IRT and linking (as described in Kolen & Brennan, 2014) to create a single uniform vertical scale for the Externalizing scale of the CBCL (and separately for the TRF) that spans multiple years of development. The approach fitted an IRT model to the externalizing problems scale separately at each age (i.e., wave). After estimating item parameters, the item parameters were then linked into a single uniform vertical scale for mothers' and teachers' reports separately. Finally, the latent externalizing factor scores were estimated for each child at each age on the same scale. This procedure is described in detail below.

The mother- and teacher-reported items of externalizing problems were analyzed with the graded response IRT model (Samejima, 1969) using the mirt package (Chalmers, 2012) in R 3.4.1 (R Core Team, 2019). The mirt package uses a maximum likelihood expectation-maximization algorithm to estimate item parameters (Bock & Aitkin, 1981). The maximum likelihood estimation procedure uses all available data for each item and provides valid inferences if the data are missing at random or completely at random. The graded response model is a more generalized version of the two-parameter logistic model for dichotomous outcomes. The graded response model allows for polytomous items that are ordinal in nature through a series of cumulative comparisons (de Ayala, 2009). The mother- and teacher-reported externalizing problem items in the current study were questionnaire items rated from 0 to 2. The graded response model takes the following general form:

$$P(X_{ij} = x_{ij} | \theta_i) = P_{x_{ij}}^*(\theta_i) - P_{x_{ij}+1}^*(\theta_i)$$

where

$$P_{x_{ij}}^*(\theta_i) = P(X_{ij} \geq x_{ij} | \theta_i) = \frac{1}{1 + e^{a_j(\theta_i \pm b_{jk})}}.$$

In this model, three parameters are of primary interest:  $a_j$ , which is an item-specific discrimination parameter,  $b_{jk}$ , which is an item-specific severity parameter (commonly referred to as difficulty in educational measurement literature), and  $\theta_i$ , which is a subject-specific latent variable representing the child's level of externalizing problems. In the above model,  $j$  represents unique items,  $k$  represents different categories that are rated, and  $i$  represents unique children. Because the items are rated from 0 to 2, there are two  $b_{jk}$  item-specific severity terms reflecting the category boundary locations. The category boundary locations reflect the point at which the probability of being in category  $k$  or lower compared with the categories above  $k$  is 50%. For example, if  $b_{j1} = 1.3$ , the interpretation would be that there is a 50% probability of being in category 0 or 1 (i.e., category  $k$  or lower) compared with category 2 (i.e., categories above  $k$ ) at this value, 1.3, on the externalizing problems trait scale. These models were fitted separately for each age (and rater) to ensure unidimensionality of the models. There may be slight shifts in the externalizing problems construct over time due to natural developmental changes (e.g., Petersen, Bates, Dodge, et al., 2015). Although these slight construct shifts are expected theoretically, the graded response model

shown above assumes unidimensionality. When spanning a wide age range, it is considered safer to fit a separate model at each age rather than a single model that spans across all ages because a model that spans across all ages is more likely to violate the unidimensionality assumption of IRT (Kolen & Brennan, 2014). Thus, we fit a separate model at each age in the present study. This approach was also applied by Petersen, Lindhiem, et al. (2018) in their creation of a vertical scale for internalizing problems across a wide age range.

After successful estimation of the IRT models, we used linking methodology to create the externalizing problems vertical scale (Kolen & Brennan, 2014). Vertical scaling attempts to place two measures that assess the same construct but differ based on severity and discrimination onto the same scale. One way to create a vertical scale is to link the two measures. The strength of the linking is enhanced if there is content that overlaps across the two measures, often referred to as common items or anchor items in educational measurement (Holland & Dorans, 2006; Kolen & Brennan, 2014). Because the items comprised by the Externalizing Problems scale do not change across the age-span used in the current study, all items are in common across the waves. Because of item parameter invariance theory, any difference in item parameter estimates should be able to be rescaled onto a single unified metric with a linear transformation (Kolen & Brennan, 2014). Linking the item parameters and the resulting latent factor scores of externalizing problems can then be performed by comparing and linearly transforming differences in discrimination and severity across the waves. The linking was performed in three steps.

1. As described above, the IRT models were fitted at each wave of data separately.
2. Vertical scaling techniques were used to link the measure over time. The `plink` package (Weeks, 2010) in R 3.4.1 (R Core Team, 2019) was used to perform the linking by using the Stocking-Lord (SL) procedure (Stocking & Lord, 1983). The SL is an iterative procedure that estimates linking constants by minimizing differences in the aggregate scores across common items. We used the SL linking procedure as opposed to other linking procedures (e.g., Haebara) because we were interested in construct-level (i.e., externalizing problems) scores but were less interested in the response to a single item. Nevertheless, there has been little empirical difference shown between the two characteristic curve linking methods, SL and Haebara (Hanson & Béguin, 2002; Kim & Lee, 2006; LeBeau, 2017).

To estimate the SL parameters, the reference age was set at 4 years of age, the first time point in the present study. The reference age set the scale to which the item parameters at subsequent ages were transformed. In other words, item parameters estimated at later ages were transformed to be on the same scale as the item parameters estimated at 4 years of age. The process of linking was done iteratively by chaining together multiple linking constants across the age-span. First, SL linking constants were estimated that linked the item parameters at age 5 to be on the same scale as the item parameters at age 4. Additional linking constants were esti-

mated between adjacent age spans, for example between 5 and 6 years of age, 6 and 7 years of age, and so on. There are two estimated scaling constants including an intercept parameter,  $B$ , and a slope parameter,  $A$ , that are used to link the item parameters onto the reference scale.

After successfully estimating the linking constants, all item parameters were then transformed to be on the age 4 scale. The transformations took the following form:

$$a(\text{age}_i) = \frac{a(\text{age}_j)}{A},$$

$$b(\text{age}_i)_k = A \times b(\text{age}_j)_k + B,$$

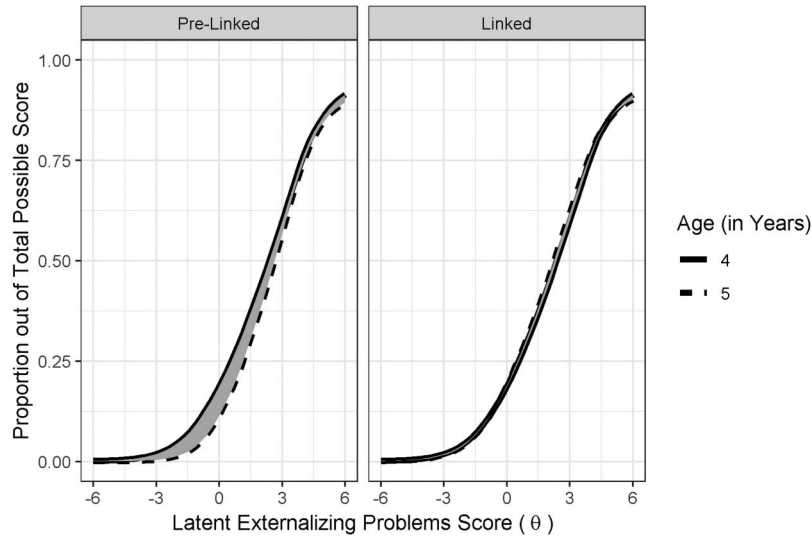
where  $a(\text{age}_i)$  and  $a(\text{age}_j)$  are discrimination parameter estimates for the common items at adjacent ages  $i$  and  $j$  respectively;  $b(\text{age}_i)_k$  and  $b(\text{age}_j)_k$  are severity parameter estimates for the common items at adjacent ages  $i$  and  $j$ , respectively, for category  $k$ ;  $A$  represents the slope scale parameter, and  $B$  represents the intercept scale parameter. To shift all item parameters to a common age 4 scale, all previous adjacent scaling constants are applied to the item parameters. For example, when shifting the item parameter estimates for 5-year-olds to the age 4 scale, a single set of scaling constants are used. However, when shifting the item parameters for 6-year-olds, two sets of scaling constants are used: first, the item parameter estimates for 6-year-olds are transformed to the scale of the 5-year-olds, and then they are transformed a second time to be on the age 4 scale. See Figure 1 for a visualization of the linking process.

3. After successfully placing item parameter estimates on a single developmental vertical scale, factor scores are calculated that represent the latent externalizing problems score with expected a posteriori (EAP) factor scores (Thissen, Pommerich, Billeaud, & Williams, 1995). The linking in the previous step scales the factor scores to be on the single developmental vertical scale while still retaining changes in means and variances over time. The factor scores are assumed to be linearly related based on the following equation:

$$\theta(\text{age } 4) = A \times \theta(\text{age}_j) + B$$

where  $\theta(\text{age } 4)$  represents the trait factor scores at age 4 (the reference scale) and  $\theta(\text{age}_j)$  represents the trait factor scores at subsequent measurement occasions. The chaining description referenced with the linking is applicable here as well.

**Growth curve models.** We fit growth curve models using the `lme` function of the `nlme` package (Pinheiro, Bates, DebRoy, & Sarkar, 2009) in R 3.4.1 (R Core Team, 2019) for hierarchical linear modeling (HLM), which handles missingness and unbalanced data (Singer & Willett, 2003). The study aimed to estimate both within-person and between-person associations between language ability and externalizing problems. To disaggregate within- and between-person effects in the models, we included predictors for both the child's mean language ability score across time (i.e., a between-person effect) and the child's person-mean-centered language ability score (i.e., language ability score at a given time point that is centered around their own mean language ability score across time; a within-person effect). Thus, the HLM growth curve models examine both the within-person and between-person asso-



*Figure 1.* The figure illustrates the effect of linking the latent externalizing problems scores,  $\theta$ , across ages, using mother-reported externalizing problems at ages 4 and 5 as an example. The left panel illustrates the test characteristic curves representing the model-implied proportion of total possible scores across the latent externalizing problems score at age 4 and 5, before the linking process. The right panel illustrates the test characteristic curves after the linking process. The shading between the age 4 and age 5 test characteristic curves represents differences between the two test characteristic curves in terms of discrimination and/or severity, where larger differences reflect scores that are less comparable. Linking minimizes differences between the discrimination and severity of the common items. Discrimination is depicted by the steepness of the slope at the inflection point of the test characteristic curve. Severity is represented by the value on the x axis at the inflection point of the test characteristic curve. The left panel indicates that the externalizing problem items showed higher severity at age 5 than at age 4. The right panel shows considerably smaller differences between the two test characteristic curves, which provides empirical evidence that the linking successfully placed the latent externalizing problem scores across age on a more comparable scale (i.e., more similar discrimination and severity of the common items).

ciation between the predictor (language ability) and outcome (externalizing problems).

HLM growth curve models fit random intercepts and slopes of externalizing problems. Model equations are below.

Nesting:

Level 1:  $t = \text{time}$  (i.e., age in months, centered at 54 months of age)

Level 2:  $i = \text{individual}$

Level 1—Within individual:

$$\text{Externalizing}_{it} = \beta_{0i} + \beta_{1i}(\text{time}_{it}) + \beta_{2i}(\text{languagePersonMeanCentered}_{it}) + e_{it}$$

Level 2—Between individual:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{languagePersonMean}_i) + r_{0i}$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{languagePersonMean}_i) + r_{1i}$$

$$\beta_{2i} = \gamma_{20}$$

$\beta_{0i}$  reflects the association with the random intercepts, centered at 54 months of age (i.e., the first time point).  $\beta_{1i}$  reflects the association with the random linear slopes.  $\beta_{2i}$  reflects a time-varying predictor.  $\gamma_{00}$  reflects the average intercept across children.  $\gamma_{10}$  reflects the average linear slope across children.  $e_{it}$  reflects the level-1 random effect (level-1 residuals).  $r_{0i}$  and  $r_{1i}$

reflect the level-2 random effects (level-2 residuals) of intercepts and slopes, respectively.

To disaggregate within- and between-person effects in the association between language ability and externalizing problems, we included both within-person effects and between-person effects in the HLM growth curve models, consistent with best practices (Curran & Bauer, 2011; Hoffman & Stawski, 2009). The between-person effects were estimated by including the child's own mean language ability score across time ( $\text{languagePersonMean}_i$ ) as a predictor of both the intercepts ( $\gamma_{01}$ ) and slopes ( $\gamma_{11}$ ) of externalizing problems (i.e., level 2). The within-person effect was estimated by centering the child's language ability score around the child's own mean, so-called person-mean centering. That is, a child's own mean language ability score across 4 to 10 years of age ( $\text{languagePersonMean}_i$ ) was subtracted from their own time-specific language ability score: that is,  $\text{languagePersonMeanCentered}_{it} = \text{language}_{it} - \text{languagePersonMean}_i$ . The within-person effect was estimated by including the person-mean-centered language ability score ( $\text{languagePersonMeanCentered}_{it}$ ) as a time-varying predictor ( $\gamma_{20}$ ) of externalizing problems (i.e., level 1). The level-1 effect is of most interest here, but for unbiased estimation, the model separates the child-level effects from the within-child effects by including the child's own mean language ability score across time. That is, the model accounts for between-child

differences in language ability to determine whether there is a within-child effect of language ability on externalizing problems (Curran & Bauer, 2011; Hoffman & Stawski, 2009).

At the between-person level, the HLM growth curve models examine children's mean values on the predictor across time in relation to their intercept and slopes on the outcome over time. At the within-person-level, the HLM growth curve models examine peoples' time-specific deviations on the predictor in relation to their time-specific deviations on the outcome over and above the effect of time (Curran, Lee, Howard, Lane, & MacCallum, 2012; Wang & Maxwell, 2015). Thus, the model examines whether within-person changes in the predictor (language ability) are associated with concomitant within-person changes in the outcome (externalizing problems). For other empirical examples using similar models, see Duckworth et al. (2010), Galla et al. (2014), and Petersen, Hoyniak, Bates, Staples, and Molfese (2018).

An assumption of models that disaggregate within- versus between-person variance is that the time-varying predictor (i.e., language ability in the present study) does not show systematic time-related change (Curran & Bauer, 2011). This assumption would be violated when using language ability as a predictor because children's language abilities increase with age on average. We addressed this assumption in two ways. First, we followed recommendations for handling systematic time-related change in the predictor by including time as a predictor in the model (Wang & Maxwell, 2015). Inclusion of time as a predictor effectively detrends the time-varying predictor in association with the outcome (i.e., controls for the portion of the within-child effect that is attributable to systematic growth; Wang & Maxwell, 2015). We thus followed best practices for disaggregating within- from between- person variance in the association between language ability and externalizing problems. As a second step, to ensure our findings were not driven by systematic time-related change in the predictor, we conducted a sensitivity analysis using age-normed standard scores of language ability as a predictor rather than raw scores.

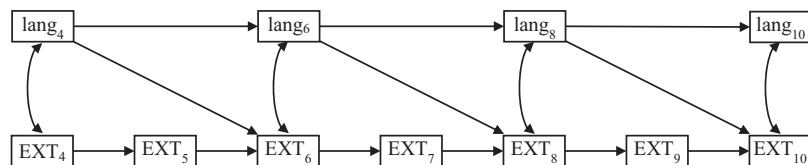
To select final models, we followed a model building sequence. Consistent with recommendations (Hox, Moerbeek, & van de Schoot, 2017), restricted maximum likelihood was used to compare models with the same fixed effects but different random effects. Full maximum likelihood was used to compare models with different fixed effects. Likelihood ratio tests were used to compare nested models. Consistent with recommendations (Long,

2012), the bias-corrected form of the Akaike information criterion (AIC; Hurvich & Tsai, 1989), the Bayesian information criterion (BIC), and pseudo- $R^2$  were used to compare non-nested models. The bias-corrected AIC (AICc) was calculated using the AICcmo-davg package (Mazerolle, 2019) in R. Pseudo- $R^2$  was calculated as the squared correlation between the model's fitted and observed values (Singer & Willett, 2003).

A time-invariant covariate (the child's sex) and a time-varying covariate (the family's income-to-needs ratio) were added to the final model. Time-invariant predictors affect the estimates of only the between-person effects, whereas time-varying predictors affect the estimates of both the within- and between-person effects (unless the time-varying predictor is person-mean-centered, in which case the person-mean-centered predictor affects the estimates of only the within-person effects). The covariate, sex, was allowed to predict the intercepts and slopes of externalizing problems. The family's income-to needs ratio was considered as a level-1 predictor and was allowed to interact with time. As a test of the secondary question of whether there are sex-related differences in the association between language ability and externalizing problems, in a separate model, we added an interaction term of the child's person-mean-centered Language Ability  $\times$  The Child's Sex (coded male = 0, female = 1).

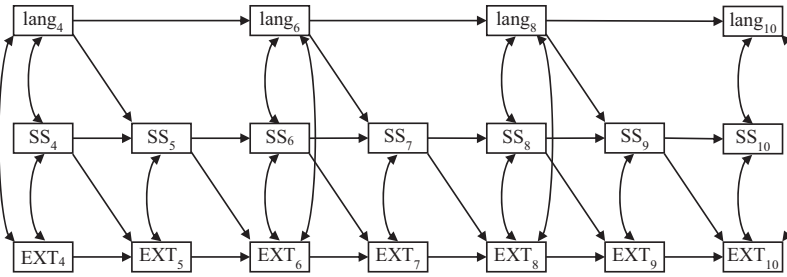
**Mediation models.** In a sequence of cross-lagged models in structural equation modeling (SEM), we examined whether social skills mediated the association between language ability and later externalizing problems. In Model 1 (see Figure 2), we examined whether language ability predicted later externalizing problems, controlling for prior levels of externalizing problems. That is, Model 1 examined whether language ability predicted within-person change in externalizing problems. In Model 2 (see Figure 3), we added social skills to the model from Model 1, and tested whether there was an indirect effect from language ability to later changes in externalizing problems via changes in social skills. We tested Models 1 and 2 with mother- and teacher-reported externalizing problems separately.

Cross-lagged models were used to test mediation because they are the most widely used models to test mediation using longitudinal data (Preacher, 2015). However, standard cross-lagged models have the limitation that they only account for temporal rank-order stability of each construct through autoregressive parameters, and they do not account for time-invariant, trait-like rank-order stability of the constructs (Hamaker, Kuiper, & Gras-



*Figure 2.* Model 1: SEM model examining whether children's language ability predicts later externalizing problems controlling for prior levels of externalizing problems, that is, whether children's language ability predicts change in externalizing problems. Models were fitted separately for mothers' and teachers' reports of externalizing problems. The subscript indicates the child's age (in years). lang = language ability; EXT = externalizing problems. Language ability was assessed every two years. In the model with mother-reported externalizing problems, externalizing problems at age 8 were regressed on externalizing problems at age 6 because mothers did not rate their child's externalizing problems at age 7. The random-intercepts model also estimated random intercepts, which are not depicted for simplicity.





*Figure 3.* Model 2: SEM model examining whether children's language ability has an indirect effect on changes in externalizing problems through social skills. That is, the model examined whether children's social skills mediated the association between children's language ability and their development of later externalizing problems. Models were fitted separately for mothers' and teachers' reports of externalizing problems. The subscript indicates the child's age (in years). lang = language ability; SS = social skills; EXT = externalizing problems. Language ability was assessed every two years. In the model with mother-reported externalizing problems, externalizing problems at age 8 were regressed on externalizing problems at age 6 because mothers did not rate their child's externalizing problems at age 7. The random-intercepts model also estimated random intercepts, which are not depicted for simplicity.

man, 2015). Therefore, standard cross-lagged models do not fully disaggregate within-person effects from between-person effects. Thus, we compared the findings from the standard cross-lagged model to findings from a random-intercepts cross-lagged model. To fit a random-intercepts cross-lagged model, we took the standard cross-lagged model and added random intercepts. Random intercepts are estimated by a latent variable for each construct whose manifest indicators are the different measurements of the construct across time, whose factor loadings are all constrained to one. By accounting for the common variance for a person's measurements across time through random intercepts, the random-intercepts cross-lagged model accounts for stable, between-person differences across time and more fully disaggregates within-person from between-person effects (Hamaker et al., 2015). That is, the random-intercepts model examined whether within-person change in social skills mediated the association between a child's language ability and their later within-person change in externalizing problems. By contrast, the standard cross-lagged model examined whether relative (rank-order) changes in social skills mediated the association between language ability and later relative changes in externalizing problems. We examined whether findings differed between the standard cross-lagged model (which is most commonly used in the literature) and the random-intercepts model to help advance understanding of developmental process.

SEM models were fitted in Mplus 6.12 (Muthén & Muthén, 2011) with full information maximum likelihood (FIML) estimation, which uses all available data and is the gold standard approach for handling missingness when data are missing at random or completely at random (Enders & Bandalos, 2001). Following recommendations, models testing mediation were fitted with bias-corrected bootstrapped confidence intervals (Hayes, 2009; Shrout & Bolger, 2002). Confidence intervals were estimated from 10,000 bootstrap samples. Model fit was examined with the root mean square error of approximation (RMSEA < .08) and comparative fit index (CFI > .95), according to established cutoffs (Schreiber, Nora, Stage, Barlow, & King, 2006). The effect size of the indirect effect was calculated as the proportion of the effect that was mediated ( $P_M$ ), which is the ratio of the indirect effect to the total effect (Wen & Fan, 2015).

**Handling missing data.** The extent of missingness for model variables is shown in Table S1 in the online supplemental materials. Missing data were handled at the scale-level (i.e., a person's missing score on a measure) and at the person-level (i.e., attrition). As a sensitivity analysis in the HLM growth curve models, we examined models with multiple imputation using the Amelia package (Honaker, King, & Blackwell, 2011) in R. Amelia uses an expectation-maximization with bootstrapping algorithm, and is well suited for longitudinal data (Honaker & King, 2010). All model variables—age, sex, income-to-needs ratio, social skills, language ability, and externalizing problems—were used to create imputed values for 100 data sets. The variables identifying the participant and participant's age were specified in the imputation model to appropriately handle the dependence of longitudinal data. Data were imputed 100 times to ensure appropriate power (Graham, Olchowski, & Gilreath, 2007). The HLM growth curve models were run on each imputed data set separately, and the results were combined using the mitools (Lumley, 2010) and mix (Schafer, 1997) packages in R, which use Rubin's (1987) rules for combining results of analyses on multiply imputed data sets. Because the results were substantially unchanged when using multiple imputation, results from the raw data are presented.

## Results

Descriptive statistics and correlations of model variables are shown in Table 1. Descriptive statistics of language ability and externalizing problems by age are shown in Table S2 in the online supplemental materials.

### Q1: Do Within-Person Changes in Language Ability Predict Within-Person Changes in Externalizing Problems?

First, we fit unconditional means models with random intercepts to the trajectories of externalizing problems. For mother-reported externalizing problems, the variance of the random intercepts was  $r_{0i} = .64$ , and the variance of the residuals was  $e_{ii} = .48$ . For teacher-reported externalizing problems, the variance of the ran-

Table 1  
Pearson Correlation Matrix of Model Variables and Descriptive Statistics

Variable	Age	Female	I:N ratio	Social skills	Language	EXTmother	EXTteacher
Age	—						
Female	.00	—					
I:N ratio	.00	.02	—				
Social skills	.28***	.15***	.21***	—			
Language	.80***	-.04*	.25***	.50***	—		
EXTmother	-.29***	-.07***	-.20***	-.35***	-.35***	—	
EXTteacher	-.06***	-.22***	-.13***	-.46***	-.20***	.35***	—
<i>M</i>	90.00	0.49	4.07	49.22	29.06	-0.71	-0.43
<i>SD</i>	24.30	0.50	3.49	11.37	5.68	1.05	1.08

Note. Age in months is estimated based on the child's grade. I:N ratio = income to needs ratio; EXTmother = mother-reported externalizing problems; EXTteacher = teacher-reported externalizing problems. Female is coded such that 1 = female and 0 = male.

\*  $p < .05$ . \*\*\*  $p < .001$ , all  $ps$  two-tailed.

dom intercepts was  $r_{0i} = .63$ , and the variance of the residuals was  $e_{ii} = .56$ . The intraclass correlation coefficient was .57 and .53 for mother- and teacher-reported externalizing problems, respectively, indicating that just over half of the variance in externalizing problems across time was between children. Second, we fit an unconditional growth model with random intercepts and random slopes of externalizing problems. Time was centered to set the intercepts at 4 years of age (i.e., the first time point). The unconditional growth model fit better than the unconditional means model (mother:  $\chi^2[3] = 1,549.38$ ,  $p < .001$ ; teacher:  $\chi^2[3] = 205.82$ ,  $p < .001$ ), so we retained random intercepts and random slopes. We observed a negative mean slope of externalizing problems (mother:  $B[5,401] = -0.01$ ,  $\beta = -0.29$ ,  $p < .001$ ; teacher:  $B[5,401] = -0.003$ ,  $\beta = -0.06$ ,  $p < .001$ ), indicating that children decreased in externalizing problems on average. The decrease in externalizing problems across ages had a small-to-moderate effect size.

We considered the functional form of children's trajectories of externalizing problems. There were four time points in which children had assessments of both language ability and externalizing problems, so the most complex polynomial we could include in a model would be quadratic. However, a model that simultaneously had random linear and random quadratic slopes failed to converge because there was insufficient variance in quadratic slopes of externalizing problems across children (when children were allowed to differ in their linear slopes). This suggests that the linear model captured most of the individual differences in growth trajectories. We then compared models with random linear slopes (and random intercepts) to models with random quadratic slopes (and random intercepts) using non-nested model comparisons. For mother-reported externalizing problems, the linear model fit better than the quadratic model in terms of AICc (linear: 13,907.35; quadratic: 14,441.30), BIC (linear: 13,947.75; quadratic: 14,481.70), and pseudo- $R^2$  (linear: .80; quadratic: .76). For teacher-reported externalizing problems, the linear model fit better than the quadratic model in terms of AICc (linear: 16,873.02; quadratic: 16,981.45), BIC (linear: 16,913.73; quadratic: 17,022.17), and pseudo- $R^2$  (linear: .68; quadratic: .66). In sum, models with linear slopes fit better than models with quadratic slopes.

We ultimately decided against using nonlinear models because (a) there were only four time points when both language ability

and behavior problems were both assessed, which limits the complexity of potential models, (b) the linear models fit the data well (mother:  $R^2 = .80$ ; teacher:  $R^2 = .68$ ), (c) models with random quadratic slopes of externalizing problems failed to converge when random linear slopes were included, (d) linear models showed better fit to the data than quadratic models, and (e) nonlinear models suffer from difficulties in interpretation, replicability, and ability to map them onto developmental theory (Grimm, Ram, & Hamagami, 2011). Because our aims were to ensure as much generalizability as possible and to understand the association between language ability and externalizing problems rather than to map the precise trajectory of externalizing problems, a linear model best fit our goals. Nevertheless findings were similar when modeling quadratic slopes.<sup>1</sup>

Third, we added predictors for the within-person ( $\gamma_{20}$ ) and between-person ( $\gamma_{01}$ ;  $\gamma_{11}$ ) associations between language ability and externalizing problems. Model results are shown in Table 2. In predicting mother-reported externalizing problems, the mean of the slopes was no longer significant when including the within- and between-person association between language ability and externalizing problems (the effect changed from  $\beta = -0.29$  to  $\beta = -0.10$ ). In terms of the between-person effect, the child's mean language ability score across time was negatively associated with their intercepts of externalizing problems and negatively associated at a trend level with their slopes of externalizing problems, with a small effect size. A poorer average language ability score across time was associated with higher initial levels of externalizing problems at age 4 and tended to be associated with less decreases of externalizing problems over time. In terms of the within-person effect, within-child changes in language ability were negatively associated with within-child changes in externalizing problems, with a moderate effect size. Findings suggest that poorer language ability (relative to one's mean) was concurrently associated with more externalizing problems (relative to one's level of externalizing problems at other time points) above and beyond one's linear slope of externalizing problems. We observed the

<sup>1</sup> The within-child association between language ability and externalizing problems held when including random quadratic slopes of externalizing problems, both for mother-reported,  $B(2,849) = -0.08$ ,  $\beta = -0.37$ ,  $p < .001$ , and teacher-reported,  $B(2,397) = -0.05$ ,  $\beta = -0.20$ ,  $p < .001$ , externalizing problems.

Table 2  
Hierarchical Linear Modeling (HLM) Growth Curve Models Without Covariates

Predictor	Mother-rated EXT					Teacher-rated EXT				
	<i>B</i>	$\beta$	<i>SE</i>	<i>df</i>	<i>p</i>	<i>B</i>	$\beta$	<i>SE</i>	<i>df</i>	<i>p</i>
Intercept	0.289	0.009	0.237	2849	.224	0.860	0.016	0.268	2397	<b>.001</b>
Time	0.004	-0.095	0.004	2849	.342	0.010	0.024	0.006	2397	.073
languageMean	-0.028	-0.108	0.008	1149	<b>&lt;.001</b>	-0.042	-0.156	0.009	1119	<b>&lt;.001</b>
languageMean $\times$ Time	0.000	-0.021	0.000	2849	.060	0.000	-0.024	0.000	2397	.098
languageCentered	-0.058	-0.257	0.005	2849	<b>&lt;.001</b>	-0.037	-0.157	0.007	2397	<b>&lt;.001</b>
Pseudo $R^2$	.82					.73				

Note. EXT = externalizing problems. Time (in months) reflects the slope term, and is centered at the first time point so that the intercept reflects the child's level at 4 years of age. languageMean refers to a given child's mean language ability across time (time invariant). languageCentered refers to a given child's language ability at a given time point that is centered around their mean language ability across time (time varying). Interaction terms with time essentially reflect the prediction of slopes of the outcome (e.g., languageMean  $\times$  Time reflects a child's average language ability across time predicting slopes of externalizing problems). Terms in bold reflect significant associations at  $p < .05$  level.

same pattern of between- and within-person associations between language ability and teacher-reported externalizing problems.

Fourth, we added covariates that might plausibly explain the association between language ability and externalizing problems. The child's sex was a time-invariant covariate that was allowed to predict both the intercepts and slopes of externalizing problems. The family's income-to-needs ratio was a time-varying covariate that was allowed to have a main effect and an interaction effect with time (i.e., to allow income to have different effects across different developmental periods). The growth curve models with predictors for the within-person and between-person associations between language ability and externalizing problems, along with covariates, served as the final models. Model results are shown in Table 3. In terms of mother-reported externalizing problems, the between-person association between language ability and slopes of externalizing problems became nonsignificant when controlling for these covariates. However, the within-person association between language ability and externalizing problems held when controlling for these covariates, and had a moderate effect size. In terms of teacher-reported externalizing problems, both the

between- and within-person associations held when controlling for these covariates.

**Sensitivity analysis.** We conducted a sensitivity analysis using age-normed standard scores (rather than raw scores) of language ability. With very few exceptions, model findings were substantially similar, indicating that the findings were not driven by systematic time-related change in the predictor (language ability).

**Q1B: Are there sex-related differences in the association between language ability and externalizing problems?** We also examined whether the child's sex moderated the association between children's language ability and their externalizing problems. There was no significant moderation by sex for mother-reported externalizing problems,  $B(2,715) = -0.01$ ,  $\beta = -0.02$ ,  $p = .420$ . There was a trend-level moderation by sex for teacher-reported externalizing problems,  $B(2,247) = -0.02$ ,  $\beta = -0.05$ ,  $p = .086$ , such that the association between language ability and externalizing problems tended to be stronger for girls than for boys, with a small effect size.

Table 3  
Hierarchical Linear Modeling (HLM) Growth Curve Models With Covariates

Predictor	Mother-rated EXT					Teacher-rated EXT				
	<i>B</i>	$\beta$	<i>SE</i>	<i>df</i>	<i>p</i>	<i>B</i>	$\beta$	<i>SE</i>	<i>df</i>	<i>p</i>
Intercept	0.307	0.008	0.246	2716	.212	0.824	0.011	0.276	2248	<b>.003</b>
Time	0.003	-0.081	0.004	2716	.499	0.015	0.047	0.006	2248	<b>.013</b>
Female	-0.179	-0.075	0.055	1136	<b>.001</b>	-0.339	-0.226	0.059	1093	<b>&lt;.001</b>
Income-to-needs ratio	-0.018	-0.068	0.007	2716	<b>.015</b>	-0.015	-0.049	0.008	2248	.081
Female $\times$ Time	0.001	0.007	0.001	2716	.526	-0.004	-0.045	0.001	2248	<b>.002</b>
Income-To-Needs Ratio $\times$ Time	0.000	-0.008	0.000	2716	.499	0.000	0.001	0.000	2248	.966
languageMean	-0.023	-0.089	0.009	1136	<b>.007</b>	-0.034	-0.141	0.010	1093	<b>&lt;.001</b>
languageMean $\times$ Time	0.000	-0.016	0.000	2716	.171	0.000	-0.029	0.000	2248	.063
languageCentered	-0.060	-0.268	0.005	2716	<b>&lt;.001</b>	-0.042	-0.182	0.007	2248	<b>&lt;.001</b>
Pseudo $R^2$	.83					.73				

Note. EXT = externalizing problems. Time (in months) reflects the slope term, and is centered at the first time point so that the intercept reflects the child's level at 4 years of age. Female is coded such that 1 = female and 0 = male. languageMean refers to a given child's mean language ability across time (time invariant). languageCentered refers to a given child's language ability at a given time point that is centered around their mean language ability across time (time varying). Interaction term of time-invariant covariates (e.g., sex) with time essentially reflect the prediction of slopes of the outcome (e.g., Female  $\times$  Time reflects sex predicting slopes of the externalizing problems). Income-to-needs ratio is a time-varying covariate. Terms in bold reflect significant associations at  $p < .05$  level.

## Q2: Are Social Skills a Potential Mechanism That Explains the Association Between Poor Language Ability and Externalizing Problems?

**Random-intercepts cross-lagged model.** In a sequence of SEM models, we examined whether social skills mediated the association between language ability and later externalizing problems, while controlling for random intercepts. In Model 1 (see Figure 2), we examined whether language ability predicted later externalizing problems, controlling for prior levels of externalizing problems. Model 1 for mother-reported externalizing problems fit the data well (RMSEA = .058, CFI = .981). Over and above controls for prior levels of externalizing problems and random intercepts, language ability at 6 years of age predicted externalizing problems two years later at 8 years of age ( $B = -0.041$ ,  $\beta = -0.13$ ,  $SE = 0.016$ ,  $p = .010$ ). However, language ability at 4 years and 8 years of age did not predict externalizing problems at 6 years of age ( $B = -0.021$ ,  $\beta = -0.07$ ,  $SE = 0.013$ ,  $p = .124$ ) or 10 years of age ( $B = -0.003$ ,  $\beta = -0.01$ ,  $SE = 0.016$ ,  $p = .841$ ), respectively, controlling for prior levels of externalizing problems and random intercepts.

Model 1 for teacher-reported externalizing problems fit the data well (RMSEA = .051, CFI = .976). Language ability at 6 years of age predicted externalizing problems at 8 years of age ( $B = -0.041$ ,  $\beta = -0.09$ ,  $SE = 0.020$ ,  $p = .040$ ). However, language ability at 4 years and 8 years of age did not predict externalizing problems at 6 years of age ( $B = 0.008$ ,  $\beta = 0.03$ ,  $SE = 0.016$ ,  $p = .619$ ) or 10 years of age ( $B = -0.022$ ,  $\beta = -0.05$ ,  $SE = 0.020$ ,  $p = .265$ ), respectively. In sum, language ability predicted later change in both mother- and teacher-reported externalizing problems (with modest effect size), so we proceeded in Model 2 to examine whether social skills mediated the longitudinal association between language ability and later externalizing problems.

In Model 2 (see Figure 3), we added social skills to the model from Model 1, and tested whether there was an indirect effect from language ability to later externalizing problems via social skills. Model 2 for mother-reported externalizing problems fit the data moderately well (RMSEA = .069, CFI = .951). None of the indirect effects were significant (age 6 externalizing problems:  $B = 0.000$ , 95% CI [-0.001, 0.003],  $\beta = 0.001$ ,  $SE = 0.001$ ,  $p = .777$ ; age 8 externalizing problems:  $B = 0.000$ , 95% CI [-0.001, 0.004],  $\beta = 0.001$ ,  $SE = 0.001$ ,  $p = .731$ ; age 10 externalizing problems:  $B = 0.000$ , 95% CI [-0.001, 0.002],  $\beta = 0.000$ ,  $SE = 0.001$ ,  $p = .856$ ).<sup>2</sup>

Model 2 for teacher-reported externalizing problems fit the data moderately well according to RMSEA (.076) but fit poorly according to CFI (.928). None of the indirect effects were significant (age 6 externalizing problems:  $B = 0.001$ , 95% CI [-0.005, 0.006],  $\beta = 0.002$ ,  $SE = 0.003$ ,  $p = .845$ ; age 8 externalizing problems:  $B = 0.000$ , 95% CI [-0.001, 0.004],  $\beta = 0.000$ ,  $SE = 0.001$ ,  $p = .879$ ; age 10 externalizing problems:  $B = 0.000$ , 95% CI [-0.004, 0.001],  $\beta = -0.001$ ,  $SE = 0.001$ ,  $p = .725$ ). Findings were similar across raters of social skills (see footnote 2). The time-invariant effect accounted for considerable variance above and beyond the autoregressive parameters; the random intercepts resulted in a 33%, 28%, and 29% mean reduction in residual variance for language ability, social skills, and externalizing prob-

lems, respectively, compared with the standard cross-lagged model (described below).

**Standard cross-lagged model.** To be consistent with prior research, we also examined the same mediation models (Models 1 and 2) in a standard cross-lagged model without random intercepts. Model 1 for mother-reported externalizing problems fit the data well (RMSEA = .027, CFI = .997). Over and above controls for prior levels of externalizing problems, language ability at 4 and 6 years of age predicted externalizing problems two years later at 6 ( $B = -0.015$ ,  $\beta = -0.05$ ,  $SE = 0.007$ ,  $p = .048$ ) and 8 ( $B = -0.025$ ,  $\beta = -0.09$ ,  $SE = 0.007$ ,  $p < .001$ ) years of age, respectively. However, language ability at 8 years of age did not predict externalizing problems at 10 years of age ( $B = 0.001$ ,  $\beta = 0.01$ ,  $SE = 0.006$ ,  $p = .819$ ), controlling for prior levels of externalizing problems.

Model 1 (see Figure 2) for teacher-reported externalizing problems fit the data well (RMSEA = .027, CFI = .996). Language ability at 4, 6, and 8 years of age predicted externalizing problems two years later at 6 ( $B = -.027$ ,  $\beta = -0.09$ ,  $SE = 0.008$ ,  $p < .001$ ), 8 ( $B = -0.041$ ,  $\beta = -0.12$ ,  $SE = 0.010$ ,  $p < .001$ ), and 10 ( $B = -0.020$ ,  $\beta = -0.06$ ,  $SE = 0.010$ ,  $p = .035$ ) years of age, respectively.

Model 2 (see Figure 3) for mother-reported externalizing problems fit the data moderately well (RMSEA = .074, CFI = .957). The indirect effect from language ability at 4 years to externalizing problems at 6 years via social skills at 5 years was significant ( $B = -0.005$ , 95% CI [-0.009, -0.002],  $\beta = -0.02$ ,  $SE = .002$ ,  $p = .003$ ). Similarly, the indirect effect from language ability at 6 years to externalizing problems at 8 years via social skills at 7 years was significant ( $B = -0.003$ , 95% CI [-0.006, -0.001],  $\beta = -0.01$ ,  $SE = .001$ ,  $p = .031$ ). Poorer language ability was associated with relative decreases in social skills, and poorer social skills, in turn, were associated with relative increases in externalizing problems. The significant indirect effect indicated that the association between poorer language ability and relative increases in externalizing problems was partially mediated by social skills. The effect size of the indirect effect was  $P_M = .33$  for predicting externalizing problems at 6 years, and was  $P_M = .09$  for predicting externalizing problems at 8 years. However, the indirect effect from language ability at 8 years to externalizing problems at 10 years via social skills at 9 years was nonsignificant ( $B = 0.000$ , 95% CI [-0.002, 0.000],  $\beta = -0.001$ ,  $SE = 0.000$ ,  $p = .503$ ). Findings were similar across raters of social skills (see footnote 2).

Model 2 (see Figure 3) for teacher-reported externalizing problems had poor fit (RMSEA = .089, CFI = .924). None of the indirect effects were significant (age 6 externalizing problems:  $B = -0.002$ , 95% CI [-0.006, 0.001],  $\beta = -0.01$ ,  $SE = 0.002$ ,  $p = .188$ ; age 8 externalizing problems:  $B = -0.002$ , 95% CI [-0.005, 0.000],  $\beta = -0.01$ ,  $SE = 0.001$ ,  $p = .186$ ; age 10 externalizing problems:  $B = 0.000$ , 95% CI [-0.001, 0.000],  $\beta =$

<sup>2</sup> Findings were also similar when examining models using mothers' and teachers' reports of social skills separately. We were unable to estimate models using only fathers' reports of social skills because of the extent of missingness and low covariance coverage.



0.000,  $SE = 0.000$ ,  $p = .759$ ). Findings were similar across raters of social skills (see footnote 2).

**Q2B: Are there sex-related differences in the association between language ability and externalizing problems?** We also examined whether the child's sex moderated the indirect effect of language ability on their externalizing problems via social skills. In multigroup models where all paths were allowed to differ between boys and girls, we examined whether the strength of the indirect effect of language ability on externalizing problems via social skills differed between boys and girls. None of the indirect effects differed between boys and girls for mother-reported externalizing problems (age 6 externalizing problems:  $B = 0.004$ ,  $\beta = 0.02$ ,  $SE = 0.004$ ,  $p = .346$ ; age 8 externalizing problems:  $B = -0.003$ ,  $\beta = -0.01$ ,  $SE = 0.003$ ,  $p = .253$ ; age 10 externalizing problems:  $B = 0.001$ ,  $\beta = 0.002$ ,  $SE = 0.001$ ,  $p = .608$ ). Likewise, none of the indirect effects differed between boys and girls for teacher-reported externalizing problems (age 6 externalizing problems:  $B = 0.001$ ,  $\beta = 0.01$ ,  $SE = 0.004$ ,  $p = .678$ ; age 8 externalizing problems:  $B = 0.000$ ,  $\beta = 0.000$ ,  $SE = 0.003$ ,  $p = .976$ ; age 10 externalizing problems:  $B = 0.000$ ,  $\beta = 0.000$ ,  $SE = 0.001$ ,  $p = .855$ ). In sum, there was no evidence that the indirect effect of language ability on externalizing problems via social skills differed between boys and girls.

## Discussion

The present study examined three questions in a longitudinal study following children from 4 to 10 years of age. First, we examined whether within-child changes in language ability predicted concomitant within-child changes in externalizing problems. Within-child changes in language ability were negatively associated with concomitant within-child changes in both mother- and teacher-reported externalizing problems. Poorer language ability (relative to one's mean) was associated with more externalizing problems (relative to one's level of externalizing problems at other time points). This within-child association of language ability held even when controlling for the family's income-to-needs ratio. The effect size of the within-child association of language ability was moderate ( $\beta_s = .18, .27$ ), and was more than three times greater than the effect size for the family's income-to-needs ratio.

Second, we examined whether social skills are a potential mechanism that explains the association between language ability and externalizing problems. To test this question, we first examined direct effects in Model 1: whether language ability predicted later changes in externalizing problems (i.e., whether language ability predicted externalizing problems two years later controlling for prior levels of externalizing problems). In standard cross-lagged models, language ability at 4 and 6 (but not 8) years of age predicted later relative changes in mother-reported externalizing problems, with a modest effect size. Language ability at 4, 6, and 8 years of age predicted later relative changes in teacher-reported externalizing problems, with a modest effect size. Despite the modest effect sizes we observed for predicting later changes in externalizing problems ( $\beta_s < .15$ ), effect sizes are often dramatically smaller when accounting for longitudinal stability in prediction, which necessitates interpreting them differently than effect sizes from cross-sectional designs (Adachi & Willoughby, 2015). This is particularly relevant for the present study because of the relatively high degree of rank-order stability in externalizing prob-

lems—the 1-year rank-order stability coefficient ranged from  $r = .64$  to  $.80$  for mother-reported externalizing problems and from  $r = .41$  to  $.68$  for teacher-reported externalizing problems (depending on the year).

Then, we examined whether there were indirect effects of language ability on later relative changes in externalizing problems via social skills at the intermediate age (i.e., social skills measured one year after language ability and one year before externalizing problems) in Model 2. Two of the direct effects observed in Model 1 showed indirect effects in Model 2. There was an indirect effect of language ability at 4 and 6 years on rank-order changes in mother-reported externalizing problems via social skills. Poorer language ability predicted relative decreases in social skills, and poorer social skills, in turn, predicted relative increases in externalizing problems. Moreover, social skills partially mediated the association between language ability and changes in externalizing problems (33% of the association was mediated in predicting externalizing problems at age 6, and 9% of the association was mediated in predicting externalizing problems at age 8). This finding suggests that social skills may be one of the mechanisms that explains how poorer language ability may lead children to develop externalizing problems. The relation that did not show a direct effect in Model 1 (language ability at 8 years predicting mother-reported externalizing problems) and the associations between language ability predicting later changes in teacher-reported externalizing problems at all years did not show an indirect effect in Model 2. However, when we conducted a mediation analysis that more fully disaggregated within-person effects from between-person effects (i.e., random intercepts cross-lagged model), we found no indirect effect from language ability to later within-person changes in externalizing problems via within-person changes in social skills. This finding raises interesting questions that we discuss later.

Third, we examined whether there were sex-related differences in the association between language ability and externalizing problems. There was not strong evidence of sex-related differences in the association between language ability and externalizing problems. The association between within-child changes in language ability and within-child changes in mother-reported externalizing problems did not differ between boys and girls. There was a trend for a somewhat stronger association between within-child changes in language ability and within-child changes in teacher-reported externalizing problems for girls than for boys. However, the effect did not reach traditional levels of significance and the effect size was small ( $\beta = .05$ ), so we are hesitant to interpret it further. Lastly, the indirect effect of children's language ability on their externalizing problems via social skills did not differ between boys and girls.

In sum, we observed that (a) within-child changes in language ability predicted within-child changes in both mother- and teacher-reported externalizing problems, (b) poor social skills may be a mechanism that partially explains how poorer language ability leads to the development of externalizing problems, and (c) the associations between language ability and externalizing problems, and indirect effects via social skills, did not strongly differ between boys and girls.

The present study advances understanding of how language ability is related to the development of externalizing problems. To our knowledge, we are aware of only one other study that has

examined whether within-person changes in language ability predict within-person changes in externalizing problems (Wang et al., 2018), providing a stronger test of developmental process. Our findings are consistent with findings from Wang et al. that within-child variation in language delay was associated with within-child variation in aggression. Findings are consistent with the notion that children's increases in language ability may at least partially explain their reduction in externalizing problems across early to middle childhood.

We also advanced prior work by examining a possible mechanism that links poorer language ability to the development of externalizing problems. The finding that social skills partially mediated the association between poorer language ability and later mother- but not teacher-reported externalizing problems suggests that social skills may be a particularly relevant mechanism that partially accounts for the association between poorer language ability and the development of later externalizing problems in the home context. We observed that social skills partially mediated the association between language ability and later externalizing problems when we did not fully account for between-person effects in a cross-lagged model, but that social skills did not mediate the association when we accounted for between-person effects in the random-intercepts cross-lagged model (Hamaker et al., 2015). This raises the interesting possibility that the overlapping variance between language ability and externalizing problems that is accounted for by social skills might reflect more stable, trait-like effects such as enduring genetic and/or biological differences, or perpetuating environmental factors, rather than time-specific developmental effects. Alternatively, the finding could be an artifact of the strong rank-order stability of the constructs and could owe to having less variance left to predict—that is, there was approximately one third less residual variance for language ability, social skills, and externalizing problems, respectively, when using the random-intercepts cross-lagged model compared with the standard cross-lagged model. The possibility that language ability, social skills, and externalizing problems partially share common causes may be important for future research to examine to better understand the developmental processes between language ability and externalizing problems. Furthermore, exploration of social skills as a mediating mechanism through different measurement strategies (i.e., measurements closer in time, measuring student social skills from a variety of perspectives) would be important for future research.

Our findings partially align with findings of Menting and colleagues (2011). They observed that peer rejection mediated the association between poorer language ability and externalizing problems, which is consistent with our finding that social skills partially mediated the association between poorer language ability and mother-reported externalizing problems. However, Menting and colleagues found that peer rejection mediated the association between poorer language ability and *teacher*-reported externalizing problems. By contrast, we did not observe that social skills mediated the association between language ability and later teacher-reported externalizing problems. This discrepancy could reflect a number of possibilities. For instance, it could reflect a difference in the measurement strategy. Menting and colleagues used peer nominations to assess peer rejection, whereas we used reports of social skills by mothers, fathers, and teachers. Because two parents (when available) made ratings about a child's social

skills in the present study, the partial mediation effect observed in the present study may have been driven by home-based rather than school-based social skills. Or, it could reflect that we used a 2-year lag between language ability and externalizing problems for assessing mediation, which could result in weaker associations compared with tests with more frequent measurements.

Findings by Menting and colleagues (2011) that peer rejection partially mediated the association between language ability and externalizing problems are broadly consistent with our findings that social skills partially mediated the association between language and externalizing problems. It could be, for instance, that poor language ability leads to the development of poorer social skills, which makes children more likely to be rejected by their peers, which in turn, leads to more externalizing problems. The importance of this finding is amplified by research showing that children with language deficits tend to have smaller peer networks and to interact with others with language deficits (Chen, Justice, Rhoad-Drogalis, Lin, & Sawyer, 2018). Moreover, the identification of social skills as a potential mediator is important because treatments may be able to target children's social skills more directly (compared with peer rejection; Bierman, 2004). The finding that social skills partially mediated the association between language ability and externalizing problems at earlier ages but not later ages suggests that it may be important to intervene earlier in development to improve children's social skills among those with language difficulties. However, these findings are tempered by the lack of a mediation effect when more fully accounting for between-person effects, which raises questions about whether an intervention targeting social skills would reduce downstream externalizing problems (that developed from poor language ability). Our findings are also consistent with prior research in the NICHD SECCYD that showed that children's language ability predicted their social skills and oppositional behavior (Russell et al., 2016). However, another study found that peer problems did not mediate the association between vocabulary and later externalizing problems (Westrupp et al., 2019), which is consistent with our findings when we more fully disaggregated within-person effects from between-person effects. In combination with prior evidence that language may serve a self-regulatory function, and that self-regulation (Petersen, Bates, & Staples, 2015) and literacy (Westrupp et al., 2019) may partially mediate the association between poorer language ability and externalizing problems, the present findings suggest that language ability may play multiple roles in the development of behavior problems.

Contrary to some prior findings, we did not find that the association between language ability and externalizing problems was stronger for boys than girls (Brownlie et al., 2004). However, our findings are consistent with other prior research showing that the association between language ability and externalizing problems does not differ between boys and girls (Petersen et al., 2013).

Although we cannot rule out the possibility of unmeasured time-varying confounds, our findings are consistent with the notion that poorer language ability plays a role in the development of externalizing behavior problems. The inference that poor language ability is causally related to the development of externalizing problems for some children is further supported by evidence from interventions. Home- and school-based interventions targeting language skills have shown improvements in language ability (Fricke et al., 2017; Roberts & Kaiser, 2011), but also improvements in

self-control (Diamond, Barnett, Thomas, & Munro, 2007) and externalizing behavior (Curtis et al., 2019). Thus, language ability appears to play a key role in the development of externalizing problems.

### Strengths and Weaknesses

The present study has several key strengths. First, we examined a performance-based measure of language ability and multiple perspectives (mother- and teacher-report) of the child's behavior, using repeated measures. Second, we examined a lengthy span of development (4 to 10 years of age) and used an IRT approach to vertical scaling to ensure that externalizing problems had construct validity and statistical comparability across the lengthy time frame. IRT and vertical scaling provide better estimates of children's externalizing problem trajectories than an item sum based on classical test theory approaches that assume that all items are equally useful and severe (Lindhiem, Bennett, Hipwell, & Pardini, 2015; Petersen, Lindhiem, et al., 2018). Third, the study examined the longitudinal association between language ability and externalizing problems, and examined the association within the individual for a stronger test of causality. Fourth, we examined a potential mediating mechanism that might explain how poorer language ability may lead to the development of externalizing problems. Fifth, we took many steps to ensure the robustness and generalizability of our findings, including using gold-standard approaches to handle missingness (FIML and verifying our findings with multiple imputation), including covariates to account for potential systematic missingness, and including multiple sensitivity analyses.

The present study also has limitations. First, because of the correlational nature of the design, and the many likely determinants of psychological development, we cannot make definitive causal inferences. Future studies should include additional time-varying covariates to control for potential confounds. Second, the lengthy 2-year gap between the predictor and outcome in the mediation models may have attenuated the association between language ability and externalizing problems. Third, social skills were based on mother-, father-, and teacher-report, rather than peer nominations. We hope that future studies will replicate and extend these findings with peer-based measures of social skills.

### Conclusion

Findings in the present study are consistent with the interpretation that poorer language ability plays a role in the development of externalizing problems. We observed that within-person changes in language ability predicted concomitant within-person changes in externalizing problems, even controlling for the family's income-to-needs ratio. Findings also provide support for the hypothesis that social skills are a mechanism that partially explains why some children with poorer language ability develop externalizing problems, but this may be limited to a between-person effect. Therefore, language ability, social skills, and externalizing problems may partially share common causes. Future research will be important to examine whether social skills are important to target in intervention, especially in early childhood, to prevent the development of externalizing problems among children with poorer language ability.

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Supplementary Table S1. Percentage of participants with scores on model variables at different numbers of time points.

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# of Time Points	0	1	2	3	4	5	6	7
Language Ability	15.3	4.0	8.1	10.8	61.7	n/a	n/a	n/a
EXT (mother-rated)	14.7	2.4	2.1	5.6	4.5	8.9	61.7	n/a
EXT (teacher-rated)	16.1	2.4	3.1	4.5	5.1	10.1	24.4	34.4
Social Skills	15.3	1.7	2.1	4.0	3.3	11.4	51.6	10.6

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Note: “EXT = externalizing problems. “n/a” indicates not applicable because, across the timeframe of the present study, language ability was only assessed at 4 time points, and mothers rated the child’s externalizing problems at only 6 time points.

Supplementary Table S2. Descriptive statistics of language ability and externalizing problems by age.

<i>M</i>	Age (Years)							
	4	5	6	7	8	9	10	
Language Ability	22.08	n/a	28.35	n/a	31.89	n/a	34.35	
Externalizing Problems (mother-rated)	0.00	-0.63	-0.77	n/a	-0.88	-0.99	-1.01	
Externalizing Problems (teacher-rated)	0.00	-0.60	-0.47	-0.52	-0.42	-0.51	-0.45	

<i>SD</i>	Age (Years)							
	4	5	6	7	8	9	10	
Language Ability	3.27	n/a	3.32	n/a	3.12	n/a	3.38	
Externalizing Problems (mother-rated)	0.94	1.01	1.02	n/a	0.99	1.00	1.01	
Externalizing Problems (teacher-rated)	0.94	1.03	0.95	1.15	1.18	1.13	1.06	

Note: "EXT = externalizing problems. "n/a" indicates not applicable because the measure was not assessed at that age.