4-1-2021

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HHS Public Access
Author manuscript
Cogn Dev. Author manuscript; available in PMC 2022 April 01.

Published in final edited form as:
Cogn Dev. 2021 ; 58: . doi:10.1016/j.cogdev.2021.101045.

Mechanisms linking socioeconomic status and academic achievement in early childhood: Cognitive stimulation and language

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Abstract

There is a strong positive association between childhood socioeconomic status (SES) and academic achievement. This disparity may, in part, be explained by differences in early environmental experiences and language development. Cognitive stimulation—including language exposure, access to learning materials, caregiver involvement in children's learning, and variety of experiences—varies by SES and may link SES to language development. Childhood language development in turn is associated with academic achievement. In the current longitudinal study of 101 children (60–75 months), SES was positively associated with cognitive stimulation and performance on language measures. Cognitive stimulation mediated the association between SES and children's language. Furthermore, children's language mediated the association between SES and academic achievement 18 months later. In addition to addressing broader inequalities in access to resources that facilitate caregivers' abilities to provide cognitive stimulation, cognitive stimulation itself could be targeted in future interventions to mitigate SES-related disparities in language and academic achievement.

Keywords

language development; home environment; cognitive development; SES-achievement gap; longitudinal studies; societal inequities

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Childhood socioeconomic status (SES) is a powerful predictor of academic achievement, such that, on average, children from high-SES backgrounds outperform their low-SES peers

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on measures of academic achievement (Brooks-Gunn & Duncan, 1997; Sirin, 2005). This gap is evident in math and reading performance even before children enter kindergarten in this United States (Lee & Burkam, 2002). These early SES-related disparities in academic achievement predict later academic achievement and educational attainment (Duncan et al., 2007; Entwisle et al., 2005). Despite wide-scale efforts to reduce the SES-achievement gap, it has remained largely unchanged over the course of the last 50 years (Hanushek et al., 2019), or has even gotten wider (Reardon et al., 2013). Taken together, these findings underscore societal inequities that deserve to be redressed through multiple approaches, disciplines, and programs.

From a developmental psychology perspective, these disparities point to the importance of identifying factors that are modifiable and could be the target of interventions to mitigate SES-related disparities in academic achievement. The present study aims to build on an extensive body of literature by connecting early environmental experience and cognitive development as mechanisms contributing to SES-related disparities in academic performance. To our knowledge, this is the first study to investigate observational assessments of environmental stimulation and language development based on both standardized and observational measures as mechanisms underlying the SES-achievement gap.

Children's receptive and expressive language varies as a function of SES. Receptive language reflects a child's understanding of language input. Expressive language reflects the words and grammatical structures that a child can produce. On average, children from high-SES backgrounds have larger and faster growing vocabularies, use more varied and complex grammatical forms, and show greater phonological awareness earlier in development than children from low-SES backgrounds (Fernald et al., 2013; Gilkerson et al., 2017; Hoff, 2003; Huttenlocher et al., 2010; Noble et al., 2007; Rowe, 2008). Disparities in the quantity and complexity of children's language emerge early in development. Recent empirical work has suggested that, on average, SES-related differences in language are observable as early 18 months of age and that by 24 months of age children from low-SES backgrounds are about six months behind their high-SES peers (Fernald et al., 2013). This gap in language persists when children start school and it influences academic achievement through elementary school (Durham et al., 2007; Hindman et al., 2010; Morgan et al., 2015; von Stumm et al., 2020; Walker et al., 1994).

The field of developmental science has focused on the importance of identifying malleable environmental factors that contribute to these differences (Fernald & Weisleder, 2015; Noble & Farah, 2013). There are many characteristics of the early physical and psychosocial environment that are thought to play a role in SES-related differences in cognitive and linguistic development, including exposure to toxins, food insecurity, harsh or unresponsive parenting, violence exposure, and limited access to educational resources (Evans, 2004; Johnson et al., 2016). A broad cluster of factors dubbed *cognitive stimulation*—including caregiver involvement in children's learning, access to developmentally appropriate learning materials, environmental complexity, and the quality and quantity of language exposure—has been proposed as one potential environmental mechanism that connects childhood SES, linguistic functioning, and academic achievement (Bradley & Corwyn, 2002; Hackman &

Farah, 2009; Rosen, Amso, & McLaughlin, 2019). SES is positively associated with cognitive stimulation (Hackman et al., 2015; Rosen et al., 2018; Rosen et al., 2020; see also early work by Bradley et al., 2001). These disparities could be related to constraints on caregivers' material resources and time, such as having to work multiple jobs, reduced access to high-quality childcare, and an inability to afford learning materials.

Early cognitive stimulation in the home is associated with both language development and academic achievement. Caregiver involvement in children's learning and access to educational materials before children begin school is positively associated with school readiness and academic achievement in elementary school (Bradley & Caldwell, 1984; Christensen et al., 2014; Crosnoe et al., 2010; Tamis-LeMonda et al., 2019). There is a well-established positive association between cognitive stimulation in the early home environment, especially the early linguistic environment, and children's language outcomes (see Brito, 2017 for a review). Early estimates by Hart and Risley (1995) suggested that, on average, children from low-SES backgrounds were exposed to 30 million fewer words by the age of three than their higher-SES peers, which was associated with children's vocabulary growth. Recent work in larger, more diverse samples using observational methods and technological advancements in all-day recordings have confirmed that, on average, children in low-SES households are exposed to less complex and less varied speech than those in high-SES households (Fernald et al., 2013; Gilkerson et al., 2017; Huttenlocher et al., 2010; Pan et al., 2005; Rowe, 2012).

Beyond linguistic exposure, other aspects of cognitive stimulation have also been shown to have a stronger influence on the development of verbal skills than to non-verbal cognitive skills (Peyre et al., 2016). Indeed, several longitudinal studies have indicated that elements of the home learning environment, including caregiver involvement in children's learning and access to learning materials, are associated with greater language performance in early childhood (Rodriguez & Tamis-LeMonda, 2011; Son & Morrison, 2010). Bruner (1983) proposed that the language used during structured, routine caregiver-child interactions—such as caregiver and child reading storybooks together or jointly engaging with learning materials—provides context for the child to use language to communicate. Ursache and Noble (2015) suggest that greater access to cognitive stimulation through exposure to complex language and an enriched home learning environment allows children to practice language and develop supporting neural networks. Taken together, these findings suggest that cognitive stimulation in the early home environment could be a mechanism underlying SES-related disparities in early language development and, ultimately, academic achievement.

The present study sought to identify mechanisms linking SES and academic achievement in early childhood, namely cognitive stimulation in the home and children's language performance. We chose to examine cognitive stimulation and language in young children as they transition to school to capture the effects of the home environment, which is still the primary context in which they experience cognitive stimulation, on children's academic performance in the critical early school years. Children's transition to school is marked by continued development of both receptive and expressive language (Farkas & Beron, 2004), as well as other cognitive skills such as executive function (Hughes et al., 2010), which play a significant role in academic achievement.

We conducted home visits with participants aged 60–75 months from a wide range of SES backgrounds. During these visits we assessed cognitive stimulation using gold-standard observational and interview measures. We measured both receptive and expressive language using a standardized test of receptive vocabulary and naturalistic language recordings, respectively. An average of 18 months after the initial visits, participants were invited back to the laboratory to complete tests of academic achievement. We hypothesized that cognitive stimulation in the early home environment would mediate the association between SES and children's language. Furthermore, we hypothesized that children's performance on measures of receptive and expressive language would mediate the association between SES and their scores on tests of academic achievement. Children from low-SES backgrounds are at higher risk of experiencing many forms of adversity, including violence exposure (Evans, 2004; McLaughlin, Grief Green, et al., 2012), which may influence cognitive development separately from cognitive stimulation. Recent models draw a distinction between the effects of different dimensions of adversity on cognitive and neural development, namely experiences of threat (e.g. violence) and deprivation (e.g. a lack of social and cognitive stimulation; McLaughlin et al., 2014). Here, we control for violence exposure in all analyses in an effort to differentiate the effects of cognitive stimulation on SES-related differences in language and academic achievement from other co-occurring forms of adversity.

Methods

Participants

Participants were 101 children aged 60–75 months (51 females) and one of the participant's caregivers. Recruitment efforts were focused on community centers, after-school programs, and pre-schools in the **Seattle** area. The race and ethnicity of the families closely matched the demographics of the Seattle area (67.3% White, 14.8% Black, 2.9% American Indian / Alaska Native, 12.8% Asian, 0.9% Native Hawaiian / Pacific Islander, 0.9% Other; 8.9% Hispanic or Latinx). In order to be considered eligible for participation, children could not demonstrate any developmental delays and English had to be the primary language spoken in the home. Two female participants were excluded from analyses due to receptive language scores two standard deviations below the mean as measured by the Peabody Picture Vocabulary Test (PPVT, Dunn & Dunn, 2007) and thus potentially experiencing developmental delay. One male participant discontinued the study before the PPVT was administered and was excluded from those analyses. All study procedures were approved by the **University of Washington** Institutional Review Board. Caregivers provided informed written consent and children provided verbal assent to participate in study procedures. We have previously published two papers using these data in which we examined associations among distinct aspects of environmental experience including SES, cognitive stimulation, violence exposure, and quality of the physical environment, with different facets of cognitive development, including executive function, attention, and memory, using behavioral tasks that are not the focus of the current report (Rosen et al., 2020; Rosen, Meltzoff, et al., 2019).

Notably, neither of these publications focuses on associations between early environmental experience, language development, and academic achievement.

Procedure : At baseline (T1), caregiver-child dyads were visited in their homes. During the visit, the child was administered the PPVT. The caregiver participated in the Early Childhood Home Observation for Measurement of Environment (HOME-EC) inventory (Bradley et al., 2001) and completed several questionnaires about demographics and violence exposure. During a break, the child and caregiver engaged in a 10-minute snack-time conversation, which was recorded and coded for the child's expressive language quality and complexity (see below). An average of a year and a half after T1 (M=17.45 months, SD=4.03), 77 caregiver-child dyads (77.8% of the baseline sample) returned to the lab for a longitudinal follow-up (T2) to complete standardized tests of academic achievement. Families who did not participate in T2 did not differ from participating families on SES, violence exposure, cognitive stimulation scores, or child language scores (see Supplemental Materials for more details).

Socioeconomic Status

SES was measured using the income-to-needs ratio and caregiver education. The income-to-needs ratio was calculated by dividing the total household income by the U.S. poverty line as defined by the 2016 census and adjusting for family size. Caregivers reported their household's annual income within ten ranges. Information about the size of each range is included in Supplemental Materials. The median income of each range was used except for the lowest and highest ranges, for which $5,000 and $200,000 were used. An income-to-needs value below 1.00 indicates that the family is living in poverty. In the present sample, 8% of participants were living in poverty according to federal standards. Because the income-to-needs ratio is based on the federal poverty line, it is not sensitive to regional differences in cost of living. This means that in some areas of the country, a family may have an income-to-needs ratio that indicates that they are not living in poverty according to federal standards but are still unable to afford necessities. In the area where data were collected, a study found that in order to afford basic needs (i.e. food, housing, transportation, health care, and child care), a family of four requires an income of approximately $75,000 per year, a family of three requires $70,000 per year, and a family of two requires $57,000 per year (Pearce, 2017). In the present study, 48.5% of our sample was below or near this self-sufficiency standard. We retain use of the income-to-needs ratio in our analyses for consistency with studies throughout the U.S. but note the income relative to the self-sufficiency standard for broader context of the financial constraints of our sample. Income-to-needs values were log-transformed for all analyses as a reflection of the hypothesis that SES associations with cognitive development are strongest at the lower end of the SES spectrum (Noble et al., 2015; Rosen et al., 2018; Rosen, Meltzoff, et al., 2019). Caregiver education was measured by the total years of education completed by the caregiver with the greatest educational attainment. The highest level of caregiver educational attainment is thought to reflect the overall access to resources for a household and has been used as a measure of SES in population-representative studies (Crosnoe et al., 2010; McLaughlin, Costello, et al., 2012; McLaughlin et al., 2011). Others have measured caregiver education using the average caregiver educational attainment (Noble et al., 2015) or the primary caregiver's educational attainment (Hoff, 2003), as they may capture additional variation in environmental experience related to SES. The pattern of results in the present study was largely consistent regardless of the measure of caregiver education used. Detailed results are presented in Supplemental Materials. The income-to-needs ratio and caregiver education were used as separate predictors of our outcome variables.

HOME Assessment

Cognitive stimulation in the early home environment was assessed using the standardized HOME-EC measure (Bradley et al., 2001). The HOME-EC includes an interview component with the primary caregiver and an observational component conducted solely by the experimenter. For every item present, the experimenter recorded a point. During the interview portion, the experimenter asked the caregiver about different toys or educational materials available to the child in the home (e.g. music, puzzles), different aspects of parenting behavior (e.g. encourages the child to learn numbers and letters), and different aspects of caregiver-child interactions (e.g. encourages the child to speak and listens). During the observational portion, the experimenter recorded information learning materials present in the environment (e.g. at least 10 books present where child can see them), different aspects of the caregiver's behavior (e.g. uses correct grammar), and different aspects of caregiver-child interactions (e.g. caregiver responds verbally to child's questions).

We defined cognitive stimulation in the home environment as access to developmentally appropriate learning materials, caregiver involvement in children's learning, exposure to complex language, and variety of enriching experiences (Rosen, Amso, & McLaughlin, 2019). We used the cognitive stimulation factor extracted from the HOME-EC by Rosen et al. (2020) using confirmatory factor analysis, which included 20 items directly related to this conception of cognitive stimulation. Details on the factor analysis and specific items are included in Supplemental Materials.

Language Measures

Receptive Language—The PPVT IV (Dunn & Dunn, 2007) is a standardized measure of receptive language. For each item, children were shown four pictures and asked to point to the picture that matched a word stated by the experimenter. Items were administered in sets of 12 and testing was discontinued when a child responded incorrectly to at least eight items in a set. A standard score was calculated as the measure of receptive language.

Expressive Language—During a break between tasks, the child was given a snack and the caregiver was asked to hold a 10-minute conversation with their child. Each child completed the same sequence of tasks before the snack break. Caregivers were not given any prompts other than to speak to their child as they normally would during a meal or snack time. The conversations were video- and audio-recorded, then later transcribed and processed using the Systematic Analysis of Language Transcripts software (SALT; Miller & Iglesias, 2007). SALT's transcription services do not double code transcripts because they have found independent transcribers who undergo their training program produce highly accurate transcripts and that the standard language measures obtained from these transcripts do not differ significantly from those that are double coded (Heilmann et al., 2008). Here, we examined child language quality and complexity. Language quality was measured by the number of different words spoken by the child. Language complexity was measured by the mean length in words of the child's conversational turns. Different words and mean turn length have demonstrated strong test-retest reliability in 5-year-old children (Heilmann et al., 2013). The same measures of caregiver language quality and complexity were extracted and used in sensitivity analyses. One recorded conversation could not be transcribed due to excessive background noise. This female participant was excluded from all analyses of expressive language.

Violence Exposure

The Violence Exposure Scale for Children Revised (VEX-R, Fox & Leavitt, 1995) was adapted as a parent-report measure given the young age of our participants. Caregivers reported on the frequency with which their child had witnessed violence (e.g. seen someone being beaten up, seen someone get shot or stabbed) and directly experienced violence (e.g. been pushed or shoved very hard, been slapped very hard). Responses were scored on a scale of zero to three (never (0), one time (1), a few times (2), lots of time (3)) and summed to create a violence exposure frequency variable that was included as a covariate in all analyses.

Academic Achievement

At the T2 follow-up assessment, three subtests of the Woodcock-Johnson IV Tests of Achievement (WJ IV) were administered to measure academic achievement (Schrank et al., 2014): Letter-Word Identification, Spelling, and Calculation. The Letter-Word Identification test required participants to identify letters and read words aloud. The Spelling test required participants to write out words that were read aloud by the experimenter. The Calculation test required participants to complete arithmetic problems. Each test was discontinued when the participant answered six consecutive items incorrectly. The Academic Skills Cluster score was a composite of the three subtests scores normed by age and was used as our measure of academic achievement.

Executive Function

Executive function was measured using children's performance on an inhibitory control task. Children were administered a "Simon says" task during the baseline home visit. Participants were instructed to imitate the experimenter's actions if they said "Simon says" prior demonstrating the action and to inhibit their response if the experimenter did not say "Simon says" prior to demonstrating the action (Carlson & Meltzoff, 2008). The experimenter administered several test trials to check children's comprehension of the rules. Children then completed 10 imitation and 10 inhibition trials. On inhibition trials, children received three points for not moving in response to the experimenter's command, two points if they flinched made a wrong movement, one point if they partially completed the action, and zero points if they fully completed the action. The task was video recorded and scored by two independent coders. Inter-rater reliability was good (Cohen's kappa: .76). The summed inhibition score was used as a measure of executive function in sensitivity analyses.

Statistical Analyses

The overarching goals of our study were twofold, which directed our choices about statistical analytic approach. First, we sought to examine the role of cognitive stimulation in the early home environment as a mechanism linking SES with language performance in early childhood. We therefore tested the paths of a standard mediation model. We used linear regression to examine the association between SES and language at T1. Specifically, we estimated a series of separate multivariate models examining income-to-needs and caregiver education as predictors of children's performance on measure of receptive language (i.e., PPVT) and expressive language (i.e., different words spoken and mean turn length) language. We then examined the relation between our two measures of SES with the cognitive stimulation measure extracted from the HOME-EC assessment. Finally, we examined the associations of cognitive stimulation with our measures of receptive and expressive language.

The second overarching goal was to investigate the role of receptive and expressive language mechanisms linking SES with academic achievement in early childhood. Again, we tested the paths of a standard mediation model. We estimated a series of separate multivariate models examining our two measure of SES as predictors of children's performance on tests of academic achievement at T2 (i.e., WJ IV Academic Skills Cluster score). Associations of SES with language at T1 were examined as described above. Finally, we examined measures of receptive and expressive language at T1 as predictors of performance on tests of academic achievement at T2. All analyses controlled for age, sex, and violence exposure. All academic achievement analyses controlled for age at T2. All results were false discovery rate (FDR)-corrected to correct for multiple tests of the same hypothesis.

Mediation—We used a bootstrapping approach to estimate the significance of indirect effects which provided a confidence interval (Hayes, 2013). Confidence intervals that do not include 0 are considered evidence for statistically significant indirect effects.

Results

Descriptive Statistics

Means and standard deviations for all study variables are presented in Table 1 and bivariate correlations between all study variables are presented in Table 2.

SES, Cognitive Stimulation, and Language

SES and Language—First, we assessed the association between SES and language (c path). SES was positively associated with receptive language. Specifically, both income-to-needs (β = .353, p = .0003, Figure 1A) and caregiver education (β = .471, p = .0003, Figure 1D) were positively associated with PPVT scores.

SES was positively associated with expressive language. Income-to-needs was associated with language quality, as measured by the number of different words expressed by the child during the snack time conversation (β =.244, p =.044, Figure 1B) and results were in the same direction, but not significant after multiple comparison correction, for caregiver education (β =.219, p =.059, Figure 1E). The associations between SES and language complexity, as measured by mean turn length, were not statistically significant after multiple comparison correction (income-to-needs: β =.202, p =.068, Figure 1C; caregiver education: β =.123, p =.249, Figure 1F).

SES and Cognitive Stimulation—We examined the association between SES and cognitive stimulation (a path). As previously reported by Rosen et al. (2020) using the same sample, there was a strong positive association between cognitive stimulation from the HOME-EC assessment with both income-to-needs (β =.478, $p < .0001$) and caregiver education (β =.547, $p < .0001$).

Cognitive Stimulation and Language—We then examined the association between cognitive stimulation and language (b path). Cognitive stimulation, as assessed by the HOME-EC, was positively associated with children's receptive language, as measured by performance on the PPVT (β =.411, p =.0003, Figure 2A), and expressive language complexity, as measured by children's mean turn length (β =.24, p =.024, Figure 2C). There was a non-significant association in the same direction for expressive language quality, as measured by the number of different words spoken (β =.184, p =.068, Figure 2B).

Sensitivity Analyses.: To account for the possibility that differences in caregiver language exposure could be driving the association between cognitive stimulation and children's language scores, we conducted sensitivity analyses controlling for corresponding caregiver language measures. The association between cognitive stimulation and children's expressive language complexity remained significant when controlling for caregivers' mean conversational turn length (β = 0.232, p =.036). Controlling for the number of different words spoken by the caregiver, cognitive stimulation was still positively, but not significantly associated with children's expressive language quality (β = 0.185, p =.069).

Mediation Analyses—Finally, we examined whether cognitive stimulation in the early home environment was a mechanism linking SES and expressive and receptive language. We found a significant indirect effect of both income-to-needs and caregiver education on PPVT scores through cognitive stimulation (95% CI: 1.009–4.292; 95% CI: .081–1.335, respectively, Figures 3A and 3B).

We estimated the indirect effect of cognitive stimulation on the association between SES and measure of expressive language, even though several pathways of the mediation models did not meet conventional thresholds of statistical significance. It is well-established that it is appropriate to examine a mediation analysis even if each of the paths does not reach conventional thresholds of statistical significance because such a conservative approach reduces power to detect mediation (Hayes, 2013; MacKinnon et al., 2007; Shrout & Bolger, 2002). We thus examined the indirect effect of SES on language complexity through cognitive stimulation and observed a significant indirect effect of both income-to-needs and caregiver education on mean turn length through cognitive stimulation (95% CI: .003–.325, 95% CI: .01–.138, respectively, Figures 3C and 3D). We did not observe a significant indirect effect of either measure of SES on expressive language quality through cognitive stimulation (income-to-needs 95% CI: −1.813–5.734; caregiver education 95% CI: −.575–2.112).

Sensitivity Analyses.: Given the temporal sequence inherent to mediation analyses, there is a general consensus in the field that mediation analyses performed on cross-sectional data should be avoided (Maxwell & Cole, 2007). Cognitive stimulation was measured using retrospective report of the children's experiences from birth through five years old and, thus, conceptually preceded performance on receptive and expressive language tasks. Nevertheless, SES, cognitive stimulation, and language scores were all measured at the same time point. We therefore conducted sensitivity analyses examining the indirect effect of SES on cognitive stimulation through receptive and expressive language. Briefly, we observed a significant indirect effect for both measures of SES on cognitive stimulation through receptive language. The confidence intervals for both models were closer to zero than in the original models where cognitive stimulation was the proposed mediator, suggesting a weaker association. In contrast, we did not observe a significant indirect effect of either measure of SES on cognitive stimulation through expressive language quality or complexity. More detailed results are presented in Supplemental Materials.

We conducted further sensitivity analyses to examine if our observed results were still significant after controlling for executive function. We reran regression and mediation analyses that involved both cognitive stimulation and language measures controlling for executive function. We did not observe any changes to the significance of any of the regression analyses. Cognitive stimulation was positively associated with receptive language and expressive language complexity, but not expressive language quality, when controlling for executive function. The significance of our mediation analyses was also largely unchanged. We observed an indirect effect of income-to-needs on receptive language through cognitive stimulation when controlling for executive function. While the indirect effect of caregiver education on receptive language through cognitive stimulation was not significant at conventional thresholds when controlling for EF, we did observe a significant indirect effect at a more liberal threshold. We continued to observe a significant indirect effect of both measures of SES on expressive language complexity through cognitive stimulation when controlling for EF. Consistent with the original results, we still did not observe a significant indirect effect of either measure of SES on expressive language quality through cognitive stimulation when controlling for EF. More detailed results are presented in Supplemental Materials.

SES, Language, and Academic Achievement

SES and Academic Achievement—In order to investigate our second overarching goal, we started by examining the association between SES and academic achievement. Though not significant after correction for multiple comparisons, both income-to-needs and caregiver education were associated with academic achievement, as measured by the Academic Skills Cluster score from the WJ-IV, in a positive direction ($\beta = .222$, $p = .061$; $\beta = .215$, $p = .061$, respectively, Figures 4A and 4B).

Language and Academic Achievement—Next, we examined the association between performance on language measures and academic achievement scores. Receptive and expressive language at T1 were positively associated with academic achievement at T2. Specifically, both PPVT scores (β =.363, p =.003, Figure 5A) and number of different words (β =.252, p =.044, Figure 5B) were positively associated with Academic Skills Cluster scores. Mean turn length was not associated with Academic Skills Cluster scores (β =.168, p =.142, Figure 5C).

Mediation Analyses—Finally, we examined whether language at T1 mediated the association between SES and academic achievement at T2. Both income-to-needs and caregiver education had a significant indirect effect on academic achievement through receptive language (95% CI: .2–3.257; 95% CI: .067–1.625, respectively, Figures 6A and 6B). We also observed a significant indirect effect of caregiver education on academic achievement through children's expressive language quality (95% CI: .003–.798, Figure 6C), but not income-to-needs (95% CI: −.008–2.157). Finally, we did not observe an indirect effect of SES on academic achievement through expressive language complexity (income-to-needs 95% CI: −.147–1.465; caregiver education 95% CI: −.047–.423).

Outliers—Casewise diagnostics indicated that there was a potential outlier in our academic achievement measure which was greater than 3 standard deviations above the mean. We reran all regression and mediation analyses without the potential outlier and did not observe many meaningful differences in the direction or effect size of any of our results. Notably, we observed an indirect effect of income-to-needs on academic achievement through expressive language quality. We no longer observed a significant indirect effect of caregiver education on academic achievement through receptive language at conventional levels of significance, but we did observe a significant indirect effect at a more liberal threshold. Detailed results are presented in Supplemental Materials.

Discussion

The present study adds to a growing body of evidence supporting the role of cognitive stimulation in the early home environment as a key environmental factor of cognitive development contributing to SES-related disparities in academic achievement. Here, we use a longitudinal design to demonstrate that cognitive stimulation is a mechanism that contributes to SES-related disparities in children's receptive and expressive language at age five. Receptive and expressive language, in turn, were positively associated with academic achievement 18 months later, and mediated the association between SES and academic achievement at age six. We demonstrate that cognitive stimulation may be an important mechanism underlying the SES-achievement gap, perhaps through its association with children's receptive and expressive language.

Our finding that cognitive stimulation mediated the association between SES and language in early childhood extends prior work on cognitive stimulation as a mechanism underlying SES-related differences in executive function (Hackman et al., 2015; Rosen et al., 2020) as well as a well-established body of work on the role of linguistic input in young children's language development (Fernald et al., 2013; Gilkerson et al., 2017; Pan et al., 2005; Rowe, 2012). Previous studies have found that the quality of caregiver speech mediates the association between SES and children's vocabulary growth in early childhood (Hoff, 2003; Huttenlocher et al., 2010). Moreover, greater conversational turns between children and caregivers is associated with structural and functional differences in brain regions that support language production, such that greater structural connectivity and activation mediate the association between language exposure and children's verbal skills (Romeo, Leonard, et al., 2018; Romeo, Segaran, et al., 2018). Here we extend findings supporting the association between caregiver linguistic input and children's language development by demonstrating that cognitive stimulation, which involves not only aspects of caregiver language but also access to learning materials, variety of experiences, and caregiver involvement in children's learning, also plays a meaningful role in language development.

An influential model of early language development proposes that language input alone is not enough to facilitate children's language learning, but that language learning is "gated" by social interaction (Kuhl, 2007). Notably, the components of cognitive stimulation measured here include not only the presence of learning materials or enriching experiences but also caregiver social interaction during child learning. A greater variety of enriching experiences and greater access to learning materials, coupled with particular kinds of caregiver social interaction, could help scaffold language development by supporting children's attention regulation (Conboy, Brooks, Meltzoff, & Kuhl, 2015) and associative learning capacities (Rosen, Amso, & McLaughlin, 2019). For example, engaging with a toy designed to teach colors, numbers, or shapes provides an opportunity to draw the child's attention to specific features of the object while linguistically labeling the salient features (Bruner, 1983). Likewise, going on outings to a museum or the grocery store together could provide greater opportunity for introducing new words or linguistic structures into caregiver-child conversation through engaging with novel stimuli. These experiences could be less typical of low-SES households due to constraints on caregiver time (e.g. the need to work multiple jobs), the inability to afford high-quality childcare during caregiver absences, and limited resources to invest in learning materials for children. Together, these constraints faced by low-SES families may contribute to the observed SES-related disparities in language development, which could potentially be mitigated through intervention.

In the present study, we observed a more consistent association between receptive language, SES, cognitive stimulation, and academic achievement than expressive language. Cognitive stimulation mediated the association between both measures of SES and receptive language, but not expressive language measures. Similarly, receptive language mediated the association between SES measure and academic achievement scores, while the indirect association was less consistently observed with expressive language measures. These inconsistencies may reflect methodological differences in our assessment of language. Receptive language was measured using a standardized test while expressive language was assessed using a brief observation of a caregiver-child interaction at home, which may not have provided sufficient variability to detect differences related to SES or cognitive stimulation. It is also possible that the caregiver's presence impacted the child's language production and future studies could assess the degree to which expressive language is influenced by these social factors. Furthermore, while we are not able to test directly here, it is also possible that because expressive language is slower to develop and more difficult to measure than receptive language (Gershkoff-Stowe & Hahn, 2013; Goldin-Meadow et al., 1976), cognitive stimulation may have a more pronounced and measurable influence on expressive language at later points in development.

Finally, we found that receptive and expressive language at age five mediated the association between SES and academic achievement 18 months later, during our T2 longitudinal assessment point. These findings are consistent with previous studies that show children's performance on language measures before entering school are a strong predictor of early academic performance (e.g., Morgan et al., 2015; Walker et al., 1994) and that early language mediates the association between SES and academic achievement in elementary school (Durham et al., 2007; von Stumm et al., 2020). Even among children from low-SES households, higher linguistic functioning in preschool is predictive of later school success (Hindman et al., 2010). This may be because a child with more advanced language skills at their disposal is better prepared to meet behavioral expectations in the typical classroom setting in the United States. For example, they might be better able to comprehend and respond to verbal instructions from the teacher, better able to participate in classroom discussions, or better able to utilize self-talk to regulate behavioral and emotional impulses. Greater facility with language could also scaffold the development of other higher-order cognitive abilities that are predictive of academic achievement, such as executive function (Blair & Razza, 2007; Daneri et al., 2019).

Language and executive function are co-developing cognitive skills in early childhood and may have a bidirectional impact on one another. Theoretical support suggests that language may play a role in the goal-directed control of attention (i.e., inhibition) and in formulating and maintaining more complex sets of rules (i.e., working memory and cognitive flexibility; Zelazo, 2015). Several longitudinal studies have indicated that early language skills predict growth in executive function in early childhood (Fuhs & Day, 2011; Kuhn et al., 2014; Vallotton & Ayoub, 2011). Indeed, a longitudinal test of the bidirectional association between language and executive function suggested that language may be a better predictor of executive function development than the other way around (Peterson et al., 2015; Slot & von Suchodoletz, 2018). Though we are not able to directly test this in the present study, it is possible that while cognitive stimulation in the present sample is associated with both language and executive function (Rosen et al., 2020), language may be scaffolding the development of executive function (e.g., Daneri et al., 2018). Future studies should investigate if cognitive stimulation facilitates growth in executive function through growth in language skills.

Several limitations to this study should be acknowledged. First, cognitive stimulation was measured as a composite of different types of enriching experiences prior to age 5. As such, we are not able to draw fine-grained conclusions about *when* cognitive stimulation could be most impactful on SES-related differences in language development. While the strength of the association between our cognitive stimulation variable and performance on language measures supports the view that enriching experiences beyond language input are important for children's language development, we are unable to disentangle which component or components are perhaps most influential in shaping language development nor to pinpoint when these aspects of the early home environment may have the greatest impact.

Second, our ability to detect an association between cognitive stimulation and expressive language was perhaps limited by our naturalistic language assessment. Our assessment period was constrained to 10 minutes and the topics of conversation were often limited to discussing the activities the child had just completed as part of the study or the snacks they were eating. Thus, it is possible that the conversations captured did not represent children's typical or maximal level of expressive language. Another study using Language Environment Analysis (LENA) demonstrates SES-related differences in children's expressive language through all-day recordings (Gilkerson et al., 2017), and this type of technology would be useful in future studies aimed at extending our findings. Additionally, the caregivers' presence for the naturalistic language assessment could have influenced children's expressive language. For example, caregivers from high SES backgrounds could have been trying to elicit more language from their children, and thus the differences in children's expressive language we observed as a function of SES could be related to caregiver behavior during the assessment rather than cognitive stimulation. Future studies should assess children's expressive language both with and without the caretaker present.

Third, as SES, cognitive stimulation, and performance on language measures were all collected at the same study time point, we were limited in our ability to draw definitive conclusions about the directionality of the association between cognitive stimulation and language development. Sensitivity analyses, however, suggested a stronger and more consistent indirect effect of SES on language measures through cognitive stimulation. Future studies should examine the potential role of cognitive stimulation as a mechanism underlying the association between SES and growth in children's receptive and expressive language capacities over time.

Fourth, we recognize that our language measures may put an undue emphasis on vocabulary disparities in children from low-SES backgrounds without equal consideration of other linguistic strengths they possess. For example, standardized measures of vocabulary, such as the PPVT, are not designed to test children's competency in other English dialects that they may speak (e.g. African American English; de Villiers, 2017). Moreover, children's performance on standardized vocabulary measures is weighted more heavily as an indicator of "typical" language development than other linguistic skills that are more culturally relevant for racial and ethnic minorities in the United States (de Villiers, 2017; Rogoff et al., 2017). These biases in our receptive language measure could limit our ability to generalize our findings across low-SES populations. It is important to consider that only 14% of our study population identified as Black and 8.9% identified as Hispanic/Latinx, racial and ethnic groups which have been historically disadvantaged by how standardized vocabulary measures are designed. Thus, the PPVT's racial and ethnic biases most likely do not account entirely for our main findings.

Relatedly, as our sample was largely white and highly educated, we are limited in our ability to generalize our findings across diverse racial and ethnic groups as well as very low-SES groups. Findings from other studies investigating associations between cognitive stimulation and children's language and academic outcomes in more racially diverse, low-SES samples are largely consistent with findings in the present study (Hirsh-Pasek et al., 2015; Rodriguez

& Tamis-LeMonda, 2011). Nevertheless, future studies should examine whether our model is replicable in more racially diverse, low-SES samples.

Finally, our study design did not allow us to investigate long-term effects of cognitive stimulation on academic achievement outcomes. There is some evidence that performance on language measures before entering school does not predict academic achievement beyond elementary school (von Stumm et al., 2020). Future studies could include more time points to test whether cognitive stimulation in the early home environment continues to be associated with academic achievement through language beyond early elementary school. It would also be valuable to design studies to look at resiliency in the pathway to academic achievement, as well as measures with a broader definition of "achievement."

Conclusions

We extend previous research on mechanisms underlying the SES-achievement gap by demonstrating with a longitudinal design that cognitive stimulation is an environmental mechanism linking SES and academic achievement through children's receptive and expressive language. Although the association between language exposure and children's language development is well-established, we demonstrate that other malleable aspects of cognitive stimulation—such as caregiver involvement in children's learning, access to learning materials, and variety of experiences—may also be important for supporting language development. Building on prior work demonstrating the importance of cognitive stimulation to the development of executive functions, the current findings suggest that cognitive stimulation in the early home environment is an environmental pathway through which SES might influence multiple aspects of children's cognitive and linguistic development. Future studies should investigate whether carefully designed, culturally appropriate interventions on specific aspects of cognitive stimulation before children begin school could help reduce SES-related disparities in receptive and expressive language to ultimately support early academic achievement in schools in the United States and more broadly.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

The authors would like to thank Zoe Miles, Kudzaiishe Irene Mapfunde, and Claudia Linares for assistance in data collection.

Funding Statement

This work was supported by the National Institute of Child Health and Human Development at the National Institute of Health (F32-HD089514 and K99-HD099203 to M.L.R.), National Institute of Mental Health at the National Institute of Health (R01-MH103291 and R01-MH106482 to K.A.M.), the Brain and Behavior Foundation NARSAD Early Investigator Award, an Early Career Research Fellowship from the Jacobs Foundation, and the IMHRO Rising Star Award to K.A.M., and by support from the University of Washington Institute for Learning & Brain Sciences.

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Highlights

- SES was positively associated with language scores at age five.
- Cognitive stimulation was positively associated with language scores at age five.
- Cognitive stimulation mediated the association between SES and language scores.
- Child language was positively associated with academic achievement 18 months later.
- Language scores mediated the association between SES and academic achievement.

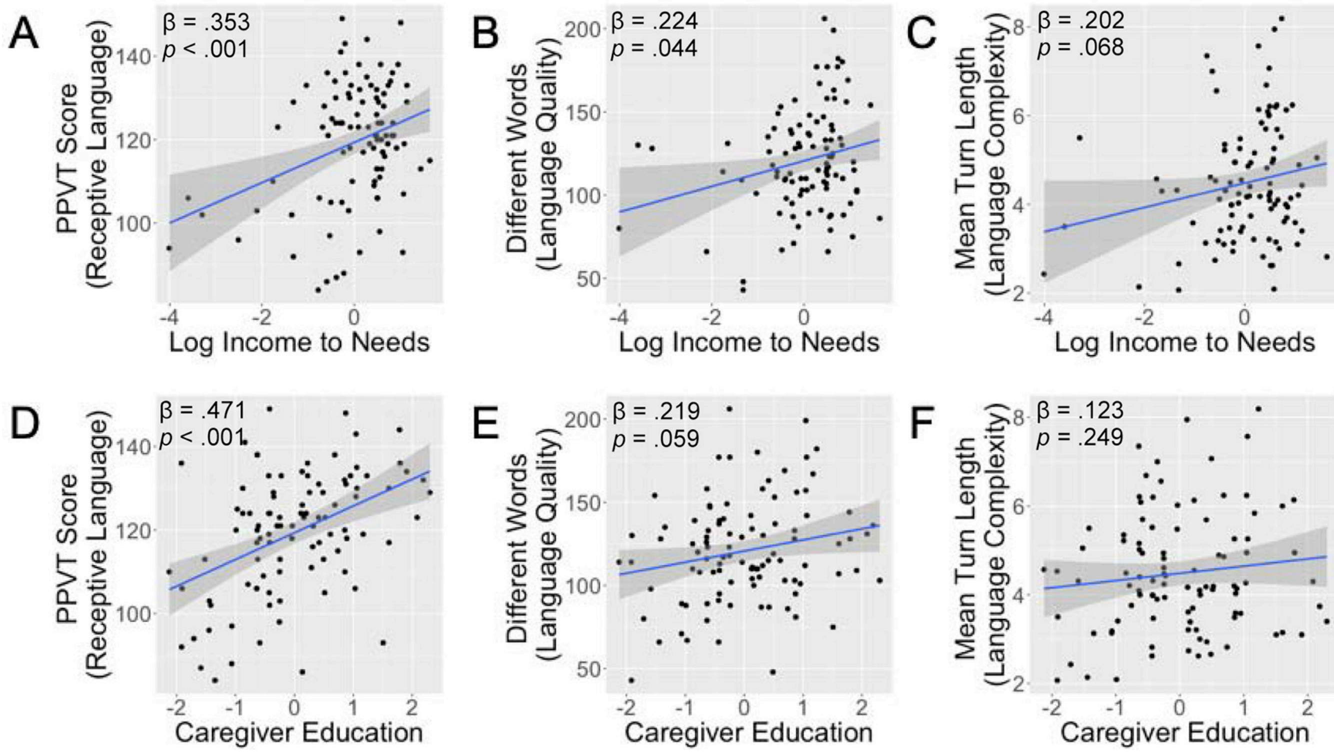

Figure 1.

Associations of SES with receptive language (A and D), expressive language quality (B and E), and expressive language complexity (C and E), controlling for age at T1, sex, and violence exposure. P-values are FDR corrected.

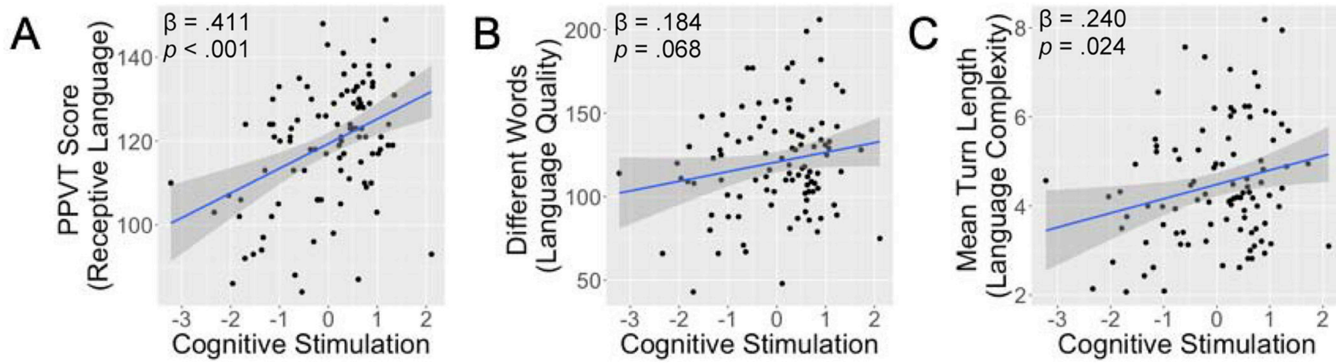

Figure 2.

Associations of cognitive stimulation with receptive language (A), expressive language quality (B), and expressive language complexity (C), controlling for age, sex, and violence exposure at T1. P-values are FDR corrected.

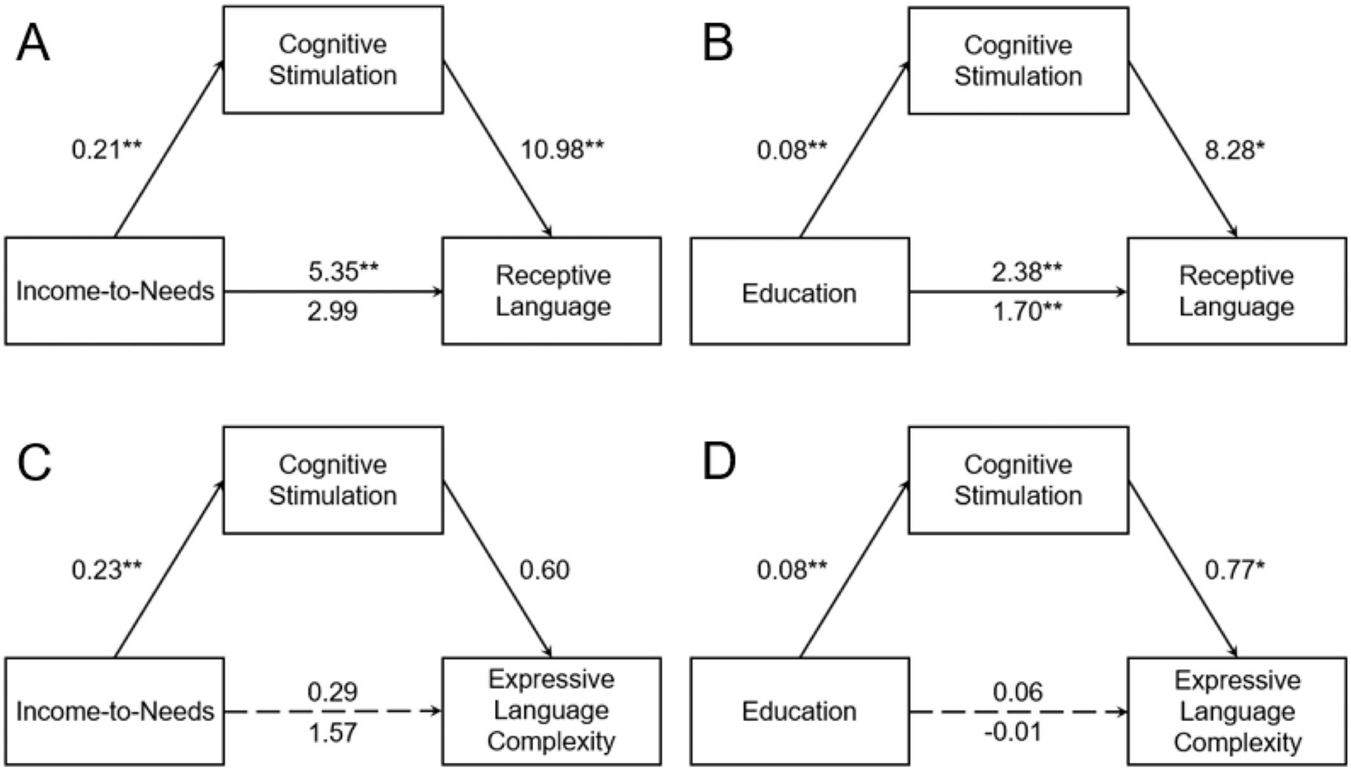

Figure 3.

Mediation Models. Cognitive stimulation mediated the associations between income-to-needs (A) and caregiver education (B) with receptive language. Cognitive stimulation also mediated the association between income-to-needs (C) and caregiver education (D) with expressive language complexity. Coefficients are unstandardized. *p < .05 **p < .01

Significant c-path

Non-significant c-path

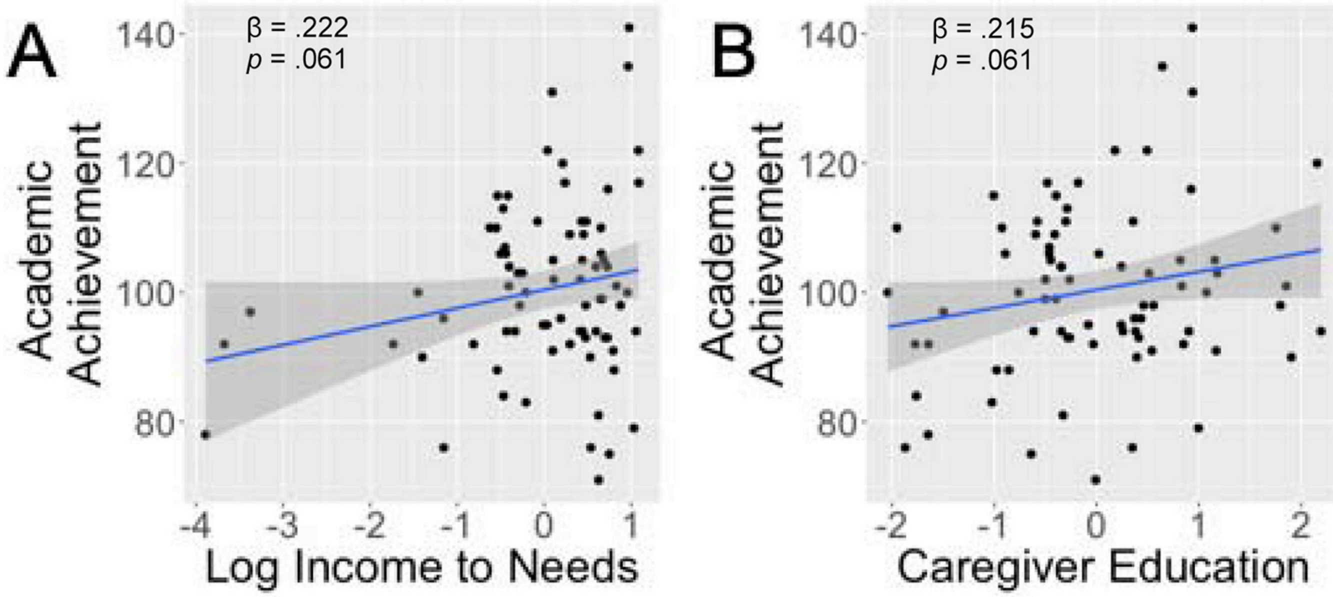

Figure 4.

Associations of income-to-needs (A) and caregiver education (B) with academic achievement, controlling for age at T2, sex, and violence exposure at T1. P-values are FDR corrected.

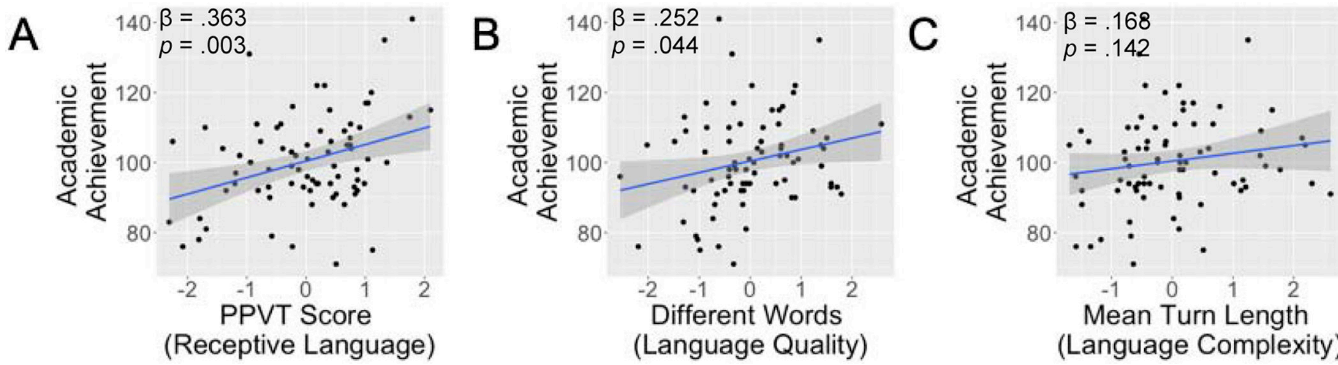

Figure 5.

Associations between receptive language (A), expressive language quality (B), and expressive language complexity (C) with academic achievement controlling for age at T2, sex, and violence exposure at T1. P-values are FDR corrected.

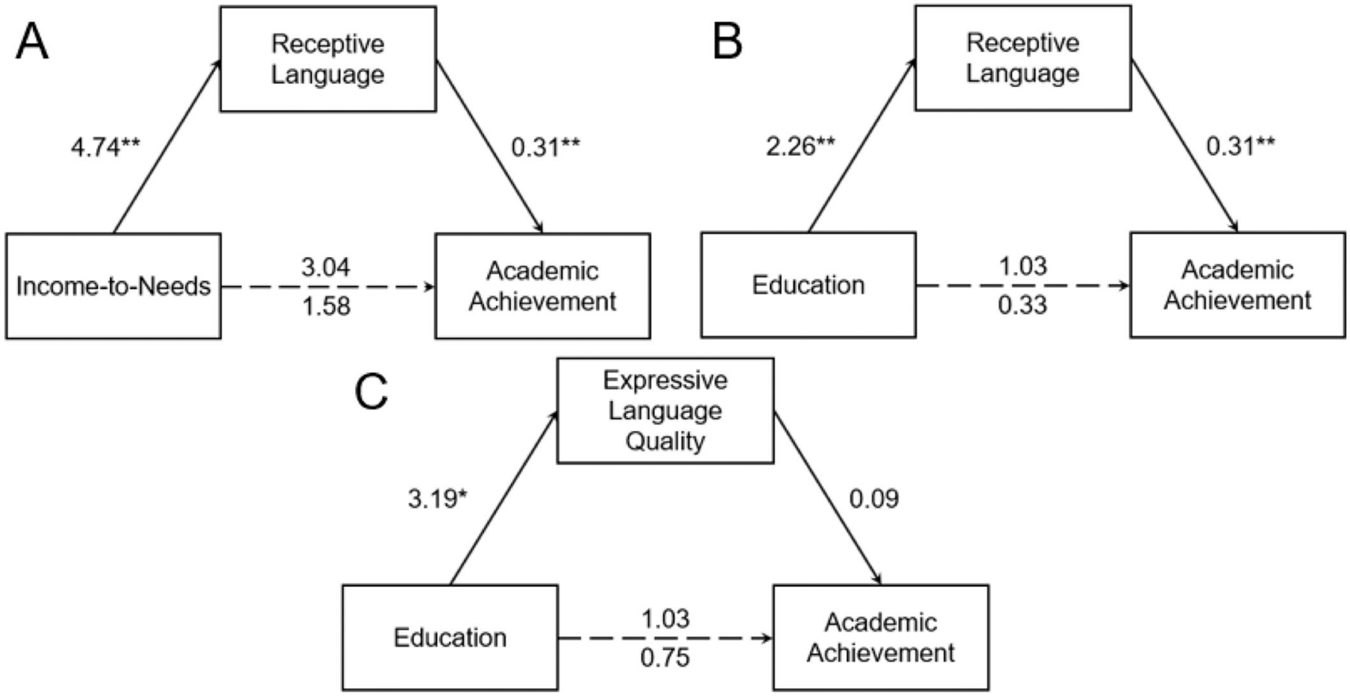

Figure 6.

Mediation models. Receptive language mediated the association between income-to-needs and academic achievement at T2 (A) as well as between caregiver education and academic achievement at T2 (B). Expressive language quality mediated the association between caregiver education and academic achievement at T2 (C). Coefficients are unstandardized. *p < .05 **p < .01

Significant c-path

Non-significant c-path

Table 1.

Means and standard deviations of all study variables.

Measure		**Mean**	***(SD)***	***Range***
Age (T1)		5.55	0.38	5 – 6.24
Age (T2)		7.00	0.46	6.13 – 8.11
Violence Exposure		3.00	3.90	0 – 20
Income		$112,530	$64,961	$5,000 – $200,000
Log Income-to-Needs		1.26	0.95	−2.54 – 2.35
Education		16.65	2.85	10 – 22
Cognitive Stimulation (total score)		15.69	3.07	5 – 20
PPVT		119.35	14.48	84 – 149
Different Words		120.77	31.36	43 – 206
Mean Turn Length		4.49	1.35	2.07 – 8.19
Academic Achievement		100.42	13.39	71 – 141

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Table 2.

Correlations of all study variables.

	Age (T1)	**Age (T2)**	**Sex**	**Violence**	**ItN (Log)**	**Edu**	**CS**	**PPVT**	**DW**	**MTL**	
Age (T1)											
Age (T2)	.702**										
Sex	.007	−.001									
Violence	.063	−.031	0.01								
ItN (Log)	.078	0	−.02	−.345**							
Edu	−.014	.073	−.09	−.359**	.493**						
CS	−.030	.014	.07	−.174	.474**	.528**					
PPVT	−.176	−.021	.059	−.314**	.399**	.513**	.457**				
DW	.080	−.079	.217*	−.136	.272**	.225*	.216*	.151			
MTL	.124	.062	.138	−.214*	.269**	.177	.277**	.243*	.641**		
AA	−.022	−.167	−.130	−.264*	.279*	.267*	.121	.410**	.241*	.152	

Note: T1 = Time 1, T2 = Time 2, Violence = total score reflecting the frequency of experiencing violence as assessed by the VEX-R; ItN (Log) = Log transformed income-to-needs ratio; Edu = Total years of education for caregiver with highest educational attainment; CS = cognitive stimulation as assessed by the HOME; PPVT = Peabody Picture Vocabulary Test standard score; DW = number of different words spoken by the child in recorded conversation with caregiver; MTL = child's mean turn length in words during recorded conversation with caregiver; AA = academic achievement as measured by the Woodcock-Johnson IV Academic Skills Cluster

* $p < .05$,

** $p < .01$