Linking Socioeconomic Status, Language Input, and Vocabulary: The Role of Syntactic Processing in School-Aged Children

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1. Introduction

Socioeconomic status (SES) has been consistently recognized as a predictor of children's language development, with differences emerging as early as infancy (e.g., Fernald et al., 2013; Newman et al., 2016; Weisleder & Fernald, 2013). Though SES has been defined in different ways in prior research, its multidimensional nature makes holistic operationalization elusive. Despite this variability, its influence on children's linguistic, cognitive, and social resources is well-documented. For example, Levine et al. (2020) found that preschool-aged children from higher-SES families demonstrated better vocabulary, syntax, and language processing than children from low- or mid-SES backgrounds. Mediating variables between SES and language outcomes, such as parenting styles and investment (e.g., Sánchez, 2023) and child characteristics and available resources (e.g., Pace et al., 2016) have been explored. However, though much robust evidence has linked SES to language outcomes, the precise mechanisms through which SES affects language-learning remain unclear.

Much of the existing literature that explores the relationship between SES and language development focuses on infants and toddlers. While this work is invaluable because it establishes that SES-related linguistic disparities surface early in life, how such disparities evolve as children grow older, enter school, and face complex language environments remains a mystery. Less is known about how SES-related differences unfold in later years, and questions still remain on how, if at all, children approach and work through them. Additionally, current related research primarily focuses on vocabulary size and acquisition. While vocabulary differences across SES are well-established (e.g., Hart & Risley, 1995; Hoff, 2003; Rowe & Goldin-Meadow, 2009), fewer studies explore whether such effects persist in other domains of language such as pragmatics (e.g., Schulze & Saalbach, 2021), semantics and morphology (e.g., Kahta et al., 2021, Rassel et al., 2020), phonology (McDowell et al., 2007), and importantly syntax and language processing (e.g., Levine et al., 2020; Weisleder & Fernald, 2013). Though lexicon is an important component of language development, it is not the only marker of language development–syntax becomes increasingly important in effective communication as children age. Thus, it is necessary to extend research beyond vocabulary and investigate whether SES-related differences carry over to syntactic acquisition to paint a more comprehensive picture of such effects on language development.

When children begin school, language development shifts from an emphasis on vocabulary to syntax as they transition from "learning to read" to "reading to learn". Syntax–the rules that govern sentence and language structure–is acquired through both innate cognitive mechanisms and external language input, though the precise dynamics of this process remain a mystery (e.g., Hyams & Orfitelli, 2015). Mastery of syntax allows individuals to comprehend, construct, and produce complex language. To successfully acquire syntax, children use two mechanisms: syntactic bootstrapping, a process that specifically utilizes context clues to infer meaning of unfamiliar words and sentence fragments (Fisher et al., 2019), and syntactic parsing, the ability to interpret sentences in real time by assigning meaning based on incoming, incremental information (Traxler, 2011). In particular, syntactic parsing is central to real-time language comprehension, as it requires interpreting sentences in real time by assigning meaning based on incoming information. Unlike vocabulary knowledge, which is often measured in isolation, parsing reflects how children process language on a moment-to-moment basis and how they extract meaning when faced with ambiguous or unfamiliar sentence structure, making syntactic parsing a key mechanism for comprehension. Both bootstrapping and parsing are shaped by exposure to different syntactic structures in language input.

In particular, one major area of syntactic growth in school is the comprehension of passives. Unlike actives (e.g., "*The dog will be quickly chasing the boy.*"), passives (e.g., *"The boy will be quickly chased by the dog."*) are created by manipulating verb phrases to place focus on the recipient rather than the doer of the action in a sentence (Keenan & Dryer, 1981). This requires the listener to identify actor and recipient roles in reversed order, making them more structurally complex than the active tense subject-verb order commonly acquired first. Passive constructions place heavy demands on complex parsing and revision mechanisms by requiring listeners to both override agent-first bias and use grammatical cues to decipher rearranged word roles. Children's ability to use passives is shaped by preference for action verbs (e.g., "throw") and their understanding of roles (i.e., agents and themes), as they struggle to decipher sentences if those relationships are unclear (Pinker et al., 1987).

Listeners interpret sentences as they unfold in real time to create maximal incrementality, or the process by which they integrate linguistic knowledge to build a complete interpretation of what is known and predict what may come next (Altmann & Mirković, 2008). This creates opportunities for temporary misinterpretations or misrepresentations, especially when the sentence structure is ambiguous or complex. Passive constructions are a prime example of this–unlike active constructions, which introduce sentences in subject-verb-recipient order, passives invert its presentation. Since passives and actives read the same until after the verb in the sentence, listeners often use agent-first bias to make assumptions about who did what to whom (e.g., Sauppe et al., 2023). Understanding complex syntactic structures such as passives requires children to engage in high-level parsing and revision of incorrect initial interpretations because of the non-canonical order in which grammar roles are presented. Studies have shown that even adults struggle with passives as they process incoming sentences word-by-word, especially when it requires revision (e.g., Huang et al., 2013).

This demand for revision is not unique to passives, as it also occurs in garden-path sentences, such as "*The boy was hitting the girl with glasses*", where incremental sentence comprehension often leads to children incorrectly assuming that the boy's instrument of choice was a pair of glasses when in fact "*with glasses*" modifies the girl who is being hit. Though garden-path sentences are a different structure compared to passives, they both require high-level syntactic parsing and revision, which children often struggle with perhaps due to underdeveloped cognitive control mechanisms (Huang et al., 2016; Omaki & Lidz, 2015) or conflict-resolution skills (Novick et al., 2008).

A potential major contributor to individual differences in these language-processing skills is the quality of home language input children receive from caregivers at home during daily interactions. For example, higher-SES children have been found to receive longer utterances, diverse vocabulary, and frequent gestures in language input, enriching their language environment and learning experience (Dong et al., 2021; Hoff, 2003; Rowe & Goldin-Meadow, 2009). On the other hand, children from lower-SES households often receive less frequent and less cognitively stimulating input, contributing to the language gap that continues to persist today (Hoff, 2003; Huttenlocher et al., 2010; Rowe, 2017). Interestingly, Weisleder & Fernald (2013) found that exposure to child-directed speech (CDS) is associated with greater present and future language processing efficiency and vocabulary growth in 19-month-olds from low-SES Latino families. Processing efficiency was found to be a crucial link between early language exposure and later vocabulary knowledge, indicating that input, processing efficiency, and vocabulary growth are inexorably intertwined in language development and affected by language input

(Weisleder & Fernald, 2013).Their research suggests that CDS facilitates language learning in infancy, rather than overheard speech, because it allows them to practice skills such as word segmentation, accessing lexical representations, and scaffolding using familiar words during sentence comprehension. Thus, the language provided by caregivers is significant in fostering language development (both syntax and vocabulary) in children.

Studies show that children from higher-SES backgrounds have been found to be more likely to have more advanced syntactic development when compared to their lower-SES counterparts (e.g., Huang et al., 2016; Huttenlocher et al., 2010; Leech et al., 2016; Omaki & Lidz, 2015), and that SES is a significant predictor of syntactic diversity both in parents' speech and children's later speech and language (Schwab & Lew-Williams, 2016). While children have been found to productively produce passives in the absence of direct modeling, they produce passives more successfully when the passive form has been modeled for, likely due to the scaffolding provided by prior exposure (Pinker et al., 1987). Limited opportunities to practice interpreting complex grammatical forms like passives from input may result in difficulties or delays in mastering higher-level parsing, contributing to broader disparities in syntactic development and later academic success across SES backgrounds.

The goals of the current study are to investigate how the children's language environment contributes to syntactic processing and receptive vocabulary across SES backgrounds. Specifically, we target syntactic processing as a mediating factor between language exposure and vocabulary development as a window into listening and learning mechanisms. Our objective is to gather more information on SES differences and their impact on real-time language processing. This logic is rooted in research that suggests that syntactic processing facilitates language comprehension (Huang & Arnold, 2016; Weisleder & Fernald, 2013), and that children from higher-SES backgrounds tend to receive more complex and varied CDS, which supports language processing efficiency (Weisleder & Fernald, 2013). We aim to assess whether children's syntactic processing skills, shaped by their language environments, contribute to successful vocabulary acquisition and how, if at all, this varies across SES.

1.1 The current study

Building on prior work demonstrating SES-related disparities in vocabulary and language processing (i.e., Weisleder & Fernald, 2013), the current study investigates whether syntactic processing mediates the relationship between SES-linked input and vocabulary development in school-aged children. It utilizes data from children across different SES and racial backgrounds collected through the Language and Cognition Lab's FamilyTalk project, which has studied language development of children in the Washington D.C., Maryland, and Virginia area. Unlike Weisleder & Fernald (2013), we focus on the effects of language input on vocabulary and language processing of older, school-aged children to see if the relationship they found between input, vocabulary, and processing efficiency in infants persists with exposure to new and taxing language environments. This study tests whether syntactic processing helps to explain the relationships between SES, language input, and vocabulary development. Our hypothesis is that syntactic processing will mediate the relationship between SES and receptive vocabulary scores in addition to the relationship between language environment and receptive vocabulary. If the findings of Weisleder & Fernald (2013) in 19-month-olds hold true for school-aged children, we will see children's syntactic processing skills as a mediator between home language input and vocabulary development across SES.

2. Methods

2.1 Subjects

For this project, 37 families of children (24 males, 13 females) ages 4- to 7- years old were recruited throughout 2022-2025 for UMD's Language and Cognition Lab's FamilyTalk study from UMD's Infant and Child Studies database, community partnerships with Howard County Head Start Centers, and online advertisements. Recruitment involved going in-person to distribute flyers about the study and collecting contact information for future communication, promoting the study online (e.g., on Facebook), and contacting families through research databases. For this study, we will be analyzing a subset of recruited families who have contributed PPVT-5 scores, LENA home recordings, and at least one eye-tracking session.

On average, parents had 18 years of education and family incomes of $129,730, and parental education and family income were found to be highly associated. The mean family income aligns with the average living wage in the DMV area, which is around $129,000 ("Living Wage Calculation", n.d.). To be eligible for the study, children had to be between 4- and 7-years old, hear and speak mostly English at home and school, live in Maryland, Virginia, or Washington D.C., and have no language impairment or other disorders. Children were from varying SES backgrounds with parental annual incomes ranging from $15,000 to $200,000. Participants were separated into two groups (low SES and high SES) with respect to the mean yearly income of the broader dataset from the FamilyTalk study ($105,000). As a result, twelve families fell below the mean yearly income and twenty five families were above the mean yearly income.

Race	Higher-SES	Lower-SES	Total
African-American/Black	6	6	12
Asian/Pacific Islander	3	3	6
Biracial/Mixed Race	3	3	6
Caucasian/White	12	0	12

Hispanic/Latino	1	0	1
Total	25	12	37

Gender	Higher-SES	Lower-SES	Total
Male	17	7	24
Female	8	5	13
Total	25	12	37

Family Income	Total number of families
< $15,000	1
$15,000-$30,000	3
$30,000-$45,000	1
$45,000-$75,000	2
$75,000-$105,000	5
$105,000-$135,000	6
$135,000-$165,000	6
$165,000-$195,000	3
<$195,000	10
Total	37

2.2 Peabody Picture Vocabulary Test (PPVT-5) (Dunn & Dunn, 2018)

The PPVT-5 was administered during the first of the two testing sessions, lasting around 20-30 minutes. Children were sat in front of a computer. They were then presented with sets of four pictures. They were then asked to indicate which of the four pictures on the screen corresponded to the word the test administrator had requested (Dunn, 2019). The test concluded when the child responded with six consecutive incorrect answers. We will specifically use PPVT-5 standardized scores so that we can compare the receptive vocabulary of children that are different ages, as the score of the participant is a reflection of language proficiency and serves as an indicator of their vocabulary knowledge. This serves as the baseline to which we will compare data and make correlations.

2.3 Language ENvironment Analysis (LENA) (Cristia et al., 2020; Cristia et al., 2021)

In order to obtain quality representations of the home-language environment, families were mailed or given a LENA recording device and a shirt with a pocket on the chest for the device to be placed in. Parents were given instructions on how to use the device and asked to record the home-language environment in two eight-hour segments over the span of two days for a total of 16 hours of recordings. Not every family was required to participate in this part of the study. These LENA recorders are naturalistic and unobtrusive, offering a more realistic and accurate characterization of the linguistic input a child receives than recording in an artificial environment, such as a lab. The LENA system provides detailed recordings of the child's speech environment, capturing both the child's vocalizations and the speech input from caregivers and others (Cristia et al., 2020). This gives us a rich dataset to examine the quality of language input children are receiving in their homes. Specifically, we will be using adult word count (AWC) per five minute segments, a metric which is automatically calculated by the LENA system. Rather than using raw AWC numbers, however, we will calculate the average of each recording's AWCs to account for differences in length of recordings, as not every family submitted all 16 hours of recordings. These samples will be selected to represent a range of SES backgrounds to increase the validity of correlations that will be established in this project.

2.4 Eye-tracking

Children also participated in a language processing task during the two testing sessions, which occurred both in person and virtually depending on availability, resources, and convenience. Seated in front of a computer in a well-lit room with minimal eye obstruction, they were first introduced to a familiar object (e.g., *"Look at the boy!"*) and subsequently two novel items (e.g, *"Look at these!"*). During this familiarization phase, participants viewed two animated events in which the first novel item acted upon the familiar item, and the familiar item acted upon the second novel item. Both the actions and the item size cued roles, as larger items were portrayed as likely agents (action performers), while smaller items were portrayed as likely themes (action recipients), priming children to predict noun roles. Then, as a series of pre-recorded sentences were played, the participant would be shown a new screen with the same three items in one static row and instructed to click on one (e.g., *"Click on the himpmeg!"*).

Four critical trial types were designed for this task. Sentences were constructed concerning two variables: tense (active or passive) and novel word status (as NP1 or NP2). The order of novel versus familiar noun phrases varied to account for interference due to alternating NP1 status (Huang et al., 2013). Verb phrases were used in between the first noun phrase and verb to maintain initial noun role ambiguity and included an auxiliary verb (e.g., "be"), adverb (e.g., "quickly"), and main verb ("eating" or "eaten"). 12 critical trials were mixed with 32 filler trials to distract from the focus of the experiment. Eye-tracking data were collected during the task via webcam on the testing laptop, capturing where, when, and how long gaze was directed during each trial. This allocation of attention provides insight into the participants' real-time processing of sentence structure and syntactic cues by capturing patterns in gaze fixation and attention shifts (Carter & Luke, 2020).

	Active	Passive
Novel word as NP1	"The *handtil* will be gently kicking the boy."	"The *handtil* will be gently kicked by the boy."
Novel word as NP2	"The boy will be gently kicking the *himpmeg*."	"The boy will be gently kicked by the *himpmeg*."

	Measure	Low-SES	High-SES
Novel NP1	Participants	10	25
	Mean	.19	.52
	Standard Deviation	.21	.39
	Range	1	1
Novel NP2	Participants	10	23
	Mean	.73	.87
	Standard Deviation	.28	.19
	Range	1	.67

3. Results

3.1 Descriptive Statistics

Prior research has shown that SES is associated with differences in the quality and quantity of home-language input (e.g., Hart & Risely, 1995; Weisleder & Fernald, 2013) and consequently variability in language outcomes like vocabulary size and language processing efficiency. We use these associations as the foundational premises of our study and build upon them by exploring potential underlying mechanisms in these relationships. Our first goal is to characterize SES-related differences within the dataset to see if and how they differ in our measures of receptive vocabulary, home-language environment, and syntactic processing. To generate those descriptive and inferential statistics, we operationalize each measure as follows:

- receptive vocabulary will be measured by standardized PPVT-5 scores; the mean PPVT-5 standardized score was 106.03 (SD = 15.38).
- home-language environment will be calculated as the average of adult word counts from 5-minute intervals captured by LENA recordings; the mean adult words per minute (AWC)

was 108.71 (SD = 44.94).

- syntactic processing will be examined through multiple lenses of overall action accuracy, action accuracy by condition, overall looks to target, and looks to the agent by condition.

We operationalize syntactic processing through both action and eye-movement measures because both offer different lenses into the on- and offline revision mechanisms children use to process novel items and less familiar sentence structure.

Table 1
Descriptive statistics and Pearson's r correlations between action data and demographic variables.

	Overall click accuracy N: 37 (25 higher, 12 lower)	Passive condition click accuracy N: 37 (25 higher, 12 lower)	Passive w/ revision condition click accuracy N: 35 (25 higher, 11 lower)
Age M: 5.22 SD: .86 Range: 4.25-7.17 N = 37	r = 0.52** CI [0.23, 0.72].	r = 0.46** CI [0.16, 0.68].	r = 0.51** CI [0.22, 0.72]
Parent Education Years M: 17.973 SD: 2.723 Range: 13-20 N = 37	0.43** CI [0.12, 0.66].	0.24 CI [-0.09, 0.53].	0.30 CI [-0.04, 0.58].
PPVT Standardized Score M: 106.027 SD: 15.376 Range: 80-133 N: 37	0.65** CI [0.41, 0.80].	0.58** CI [0.31, 0.76].	0.49** CI [0.18, 0.71].
Words/Min M: 108.711 SD: 44.943 Range: 24-243.12 N: 37	0.55** CI [0.28, 0.74].	0.55** CI [0.28, 0.74].	0.57** CI [0.29, 0.76].

Effects marked with * if $p < .05$ and ** if $p < .01$; CI indicates 95% intervals

To understand relationships across various metrics in our sample, we carried out a series of Pearson's correlations. Across all participants (N = 37), overall click accuracy was positively associated with age ($r = .52$, CI [.23, .72], $p < .01$), indicating that syntactic processing improves with development across the sampled age range. Receptive vocabulary was strongly correlated with overall accuracy ($r = .65$, CI [.41, .80], $p < .01$). Adult words per minute were also significantly correlated with overall accuracy ($r = .55$, CI [.28, .74], $p < .01$). Parent education showed a positive, moderate association ($r = .43$, CI [.12, .66], $p < .01$). A similar pattern is seen in click accuracy for the passive trials of the eye-tracking task. Passive click accuracy was significantly associated with age ($r = .46$, $p < .01$), PPVT-5 scores ($r = .58$, $p < .01$), and AWC ($r = .55$, $p < .01$). In passive trials requiring revision, performance remained significantly associated with age ($r = .51$, $p < .01$), PPVT ($r = .49$, $p < .01$), and AWC ($r = .57$, $p < .01$). Across task conditions, vocabulary and language exposure showed robust and consistent associations with syntactic processing performance.

Table 2
Descriptive statistics and Pearson's r correlations between eye-movement data and demographic variables.

	Looks to target overall N: 36 (24 higher, 12 lower)	Looks to target in passive w/ revision condition N: 25 (18 higher, 7 lower)	Looks to target in passive w/o revision condition N: 23 (18 higher, 7 lower)
Age M: 5.22 SD: .86 Range: 4.25-7.17 N: 37	0.49** [0.19, 0.704].	-0.47* [-0.729, -0.091].	0.37 [-0.033, 0.666].
Parent Education Years M: 17.973 SD: 2.723 Range: 13-20 N: 37	0.08 [-0.258, 0.395].	-0.26 [-0.592, 0.153].	0.16 [-0.25, 0.523].

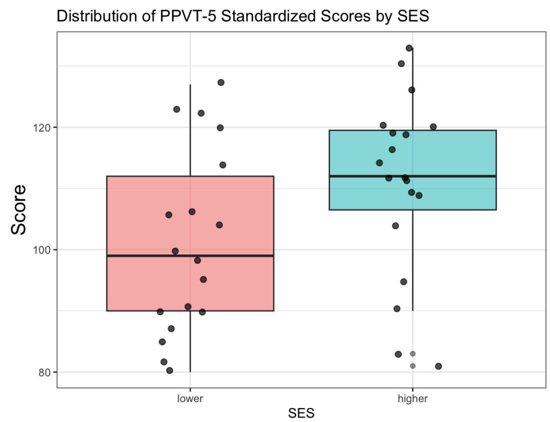
PPVT Standardized Score M: 106.027 SD: 15.376 Range: 80-133 N: 37	0.32 [-0.009, 0.587].	-0.34 [-0.647, 0.066].	0.32 [-0.082 , 0.638].
Words/Min M: 108.711 SD: 44.943 Range: 24-243.12 N: 37	0.33 [0, 0.593].	-0.37 [-0.667, 0.03].	0.11 [-0.294 , 0.487].

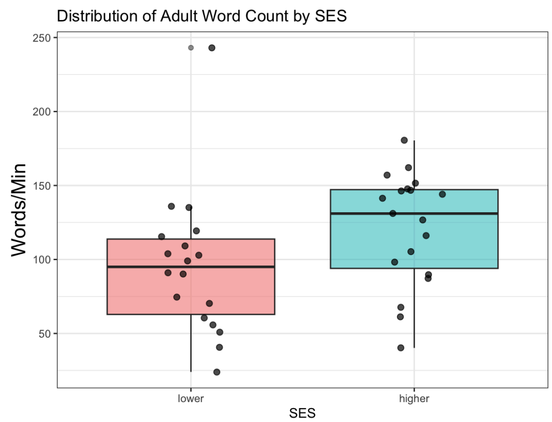
Effects marked with * if $p < .05$ and ** if $p < .01$; CI indicates 95% intervals

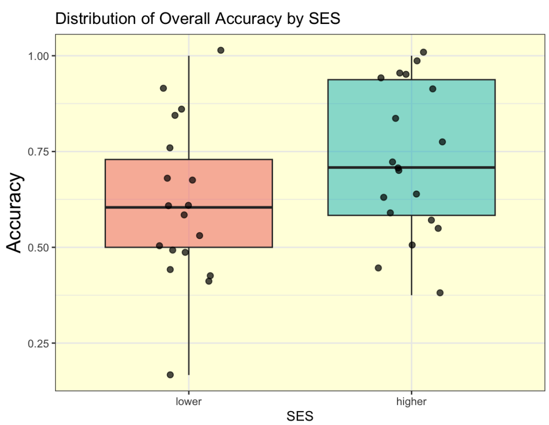
Eye-tracking analyses were conducted on a subset of participants (Ns = 23-36 depending on the condition). Overall looks to target were positively associated with age ($r = .49$, CI [0.19 , 0.704], $p < .01$), as were looks to target in passive trials that did not require revision ($r = 0.37$, CI [-0.033, 0.666], $p > .07$). However, looks to target in passive trials requiring revision were negatively associated with age ($r = -.47$, CI [-0.729, -0.091], $p = .02$). This somewhat follows what was found in action data, providing some support for syntactic processing improving with age. Receptive vocabulary, home language input, and parent education years were all negatively associated with looks to target in passive trials requiring revision, which is perhaps a reflection of a small subset of data. Nevertheless, the overall pattern somewhat reflects what was demonstrated in the action data: that syntactic processing is associated with vocabulary and home language input.

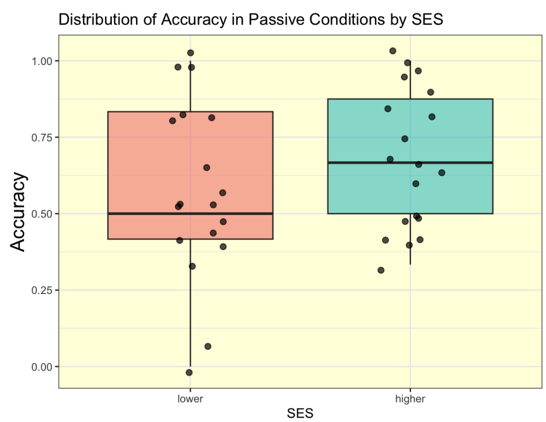
3.2 SES Effects

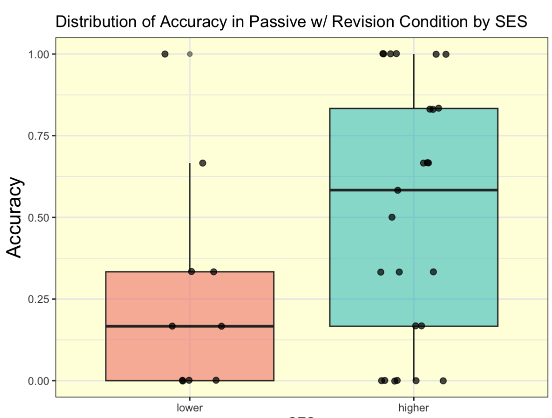
To explore whether SES-related differences exist in the vocabulary, syntactic processing, and home-language input of school-aged children, independent-samples t-tests were conducted between the lower- and higher-SES groups to compare group means for PPVT-5 standardized scores, average adult words per five minutes, and both action and eye-movement data in the language task (as well as their individual conditions). The mean split in income was $129,729, with twelve families below the median yearly income and twenty five families above it.











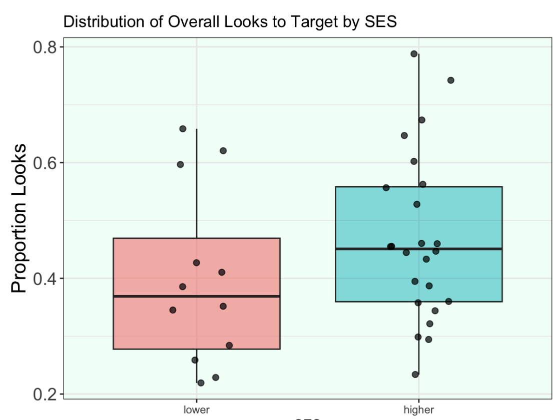


Fig. 1. Box-and-whisker plot displaying group differences for PPVT-5 standardized scores, adult words per minute, action conditions (yellow background), and eye-movement conditions (green background).

We found that children from the higher-SES group were exposed to more home language input (lower-SES group M = 95.63; higher-SES group M = 121.1; p = .002), aligning with previous literature on SES-related differences in the quality and quantity of language provided in the home environment (e.g., Weisleder & Fernald, 2013). Differences in vocabulary size approached significance (lower-SES group M = 101.11; higher-SES group M = 110.68; p = .058), with children from the higher-SES group demonstrating larger receptive vocabulary. Additionally, children from the higher-SES group performed significantly more accurately than their lower-SES counterparts in clicking the target in the syntactic processing task (lower-SES group M = .61; higher-SES group M = .73; p = .01). Passive trial accuracy differences approached significance (lower-SES group M = .58; higher-SES group M = .68; p = .06), as did passive trials with revision accuracy (lower-SES group M = .27; higher-SES group M = .52; p = .07).

Group differences were also present in each of the eye-movement measures, though not all were statistically significant. Children from the higher-SES group had overall more looks to target (lower-SES group M = .4; higher-SES group M = .47; p = 0.2), as well as in passive trials requiring revision (lower-SES group M = .4; higher-SES group M = .47; $p = 0.08$) and not requiring revision (lower-SES group M = 0.58; higher-SES group M = 0.69; $p = 0.36$).

3.3 Regressions

To examine whether syntactic processing mediates the relationship between language environment and receptive vocabulary, and separately, whether it mediates the relationship between SES and receptive vocabulary, we utilized multiple regression models. First, we fit a series of models to test the direct relation between receptive vocabulary (PPVT-5 scores) and home language input (average AWC per five-minute segments), home language input and syntactic processing (overall click accuracy), and receptive vocabulary and syntactic processing, respectively. Then, using mediation analysis, we assessed whether syntactic processing mediated the relationship between all three variables. The same approach was used to determine if syntactic processing mediates the relationship between home language input & receptive vocabulary. The goal of these analyses was to clarify the role of syntactic processing in shaping language development across SES backgrounds.

3.3.1 Home Language Input As a Predictor of Receptive Vocabulary

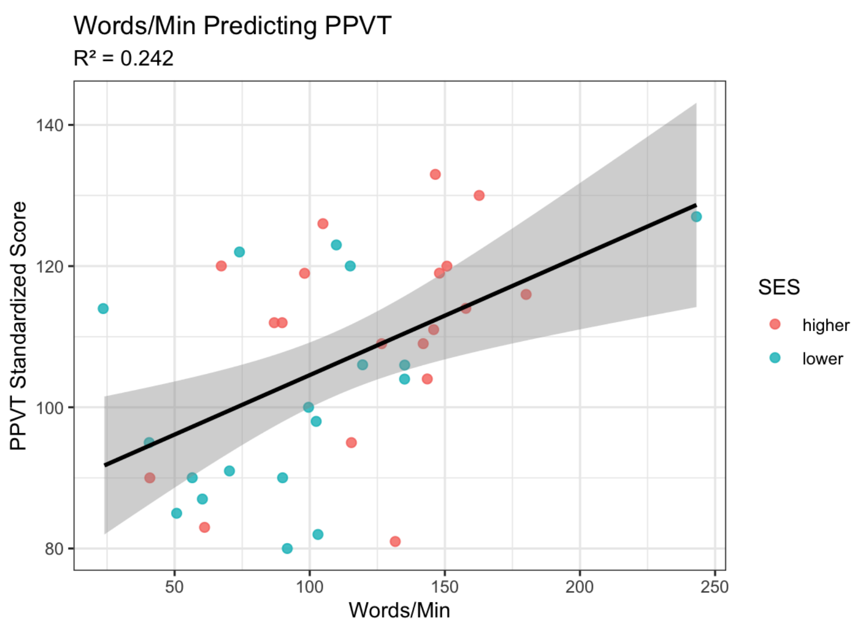


Fig. 2. A linear regression model was run to observe the relationship between adult words per minute and PPVT-5 standardized scores.

The first model testing the relationship between AWC as a predictor of PPVT-5 scores revealed that home language input significantly predicted receptive vocabulary scores ($\beta = 0.49$, $p = .002$; $t(35) = 3.35$). Adult word count explained 24% of the variance in PPVT-5 standardized scores. Even after controlling for age, the overall model was significant ($F(2, 34) = 7.32$, $p = .002$), explaining 30% of the variance in receptive vocabulary, demonstrating that language exposure contributes to vocabulary development beyond the effects of general maturation.

3.3.2 Home Language Input as a Predictor of Syntactic Processing

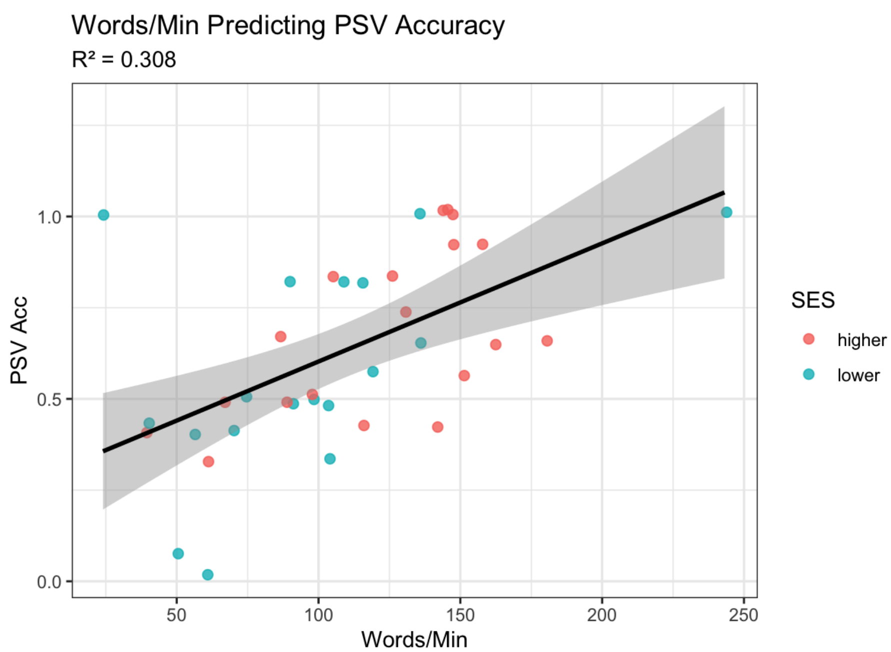


Fig. 3. A linear regression was run to observe the relationship between adult words per minute and overall action accuracy.

The second model fitted to test AWC as a predictor of overall click accuracy found that home language input significantly predicted syntactic processing ($\beta = .55$, $p < .001$; $t(35) = 3.92$), with home language input explaining 31% of the variance in overall action accuracy. The findings were still significant after controlling for age ($F(2, 34) = 12.60$, $p < .001$), and the model still explained 42.6% of the variance in syntactic processing–indicating that language exposure contributes to school-aged children's syntactic processing.

3.3.3 Syntactic Processing as a Predictor of Receptive Vocabulary

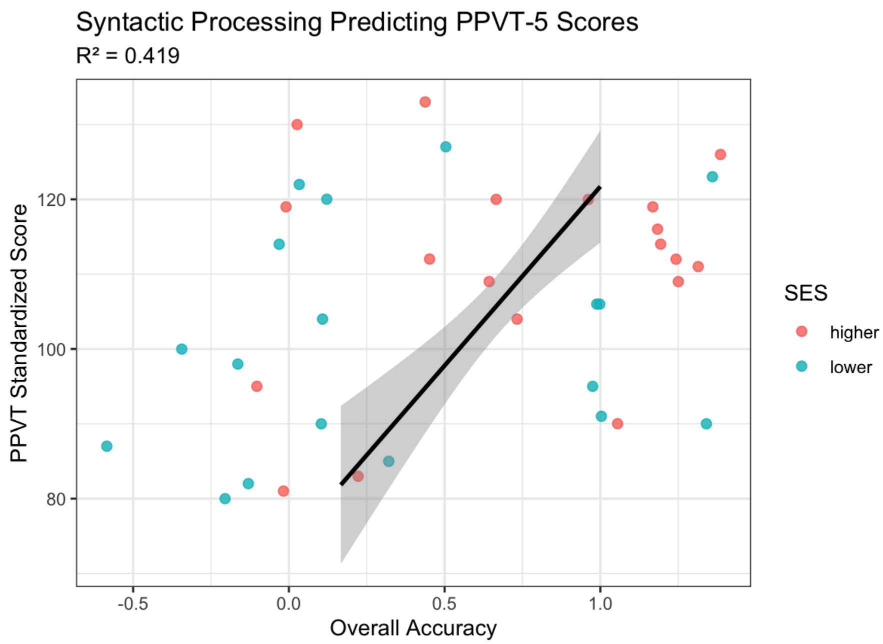


Fig. 5. A linear regression was run to observe the relationship between PPVT-5 standardized scores and overall click accuracy in the syntactic processing task.

Finally, the last model run to test syntactic processing as a predictor of receptive vocabulary revealed that overall click accuracy significantly predicts PPVT-5 standardized scores (β = 0.65; p < .001, $t(35) = 5.02$); syntactic processing explained 42% of the variance found in receptive vocabulary. Again, age was controlled as a covariate, and the overall model was significant ($F(2, 34) = 16.92$, $p < .001$), explaining 49.9% of the variance in PPVT-5 scores.

3.3.5 Mediation Analysis

To examine the relationship between all three measures (syntactic processing, receptive vocabulary, and home language input), we first created a base model where PPVT-5 scores were predicted by AWC (N = 37). When examined alone, AWC significantly predicted PPVT (β = 0.49, $p = .02$), indicating that more home language exposure was associated with higher vocabulary scores. Then, we created complex models where PPVT-5 scores were predicted by AWC and a measure of syntactic processing. Models 1-3 analyzed click data, representing offline sentence comprehension, as it is measured by accuracy of target selection. Models 4-6 analyzed eye-movement data, representing real-time language comprehension, as it is measured by looks to target over the course of the trial. Finally, we evaluated whether there were significant differences between our base model and any of our complex models (Models 1-6), we utilized maximum likelihood testing.

The results are displayed in the table below. All but one model were found to be insignificantly different from the base model (PPVT ~ AWC). Model 1 (overall click accuracy) was significant ($\chi2(1) = 6.69$, $p = 0.01$) when compared to the base model, indicating that offline sentence comprehension plays a role in the relationship between home language input and vocabulary scores. However, action data was not found to contribute to the base model when isolating each type of task trial. None of the eye-movement models (Models 4, 5, & 6) significantly differed from the base model, which may be attributable to variables such as distracting environments or individual processing differences.

Table 4

Base Model (M0) versus .	Chi square ($\chi2$)	*p*-value
Model 1: Overall Click Accuracy	$\chi2(1) = 6.69$	$p = 0.01$**
Model 2: Passive Click Accuracy	$\chi2(1) = 2.32$	$p = 0.14$
Model 3: Passive w/ Revision Condition Click Accuracy	$\chi2(1) = 0.38$	$p = 0.54$
Model 4: Looks to Target Overall	$\chi2(1) = 2.96$	$p = 0.1$

Model 5: Looks to Target in Passive w/ Revision Condition	$\chi 2(1) = 1.49$	$p = 0.25$
Model 6: Looks to Target in Passive w/o Revision Condition	$\chi 2(1) = 1.64$	$p = 0.19$

Effects marked with * if $p < .10$ and ** if $p < .05$

A bootstrapped causal mediation analysis was conducted to examine whether syntactic processing (overall click accuracy) mediated the relationship between home language input (AWC) and receptive vocabulary (PPVT-5 standardized score). Overall click accuracy was chosen as the syntactic processing metric because it was found to be the strongest predictor when added into the regression model (β = 0.54, $p = .001$). The total effect of language input on vocabulary was found to be significant (β = 0.49, $p < .001$). However, the direct effect of language input on vocabulary when controlling for syntactic processing was not statistically significant (β = 0.19, $p = .214$), suggesting that children's sentence comprehension mediates parent language input and vocabulary learning.

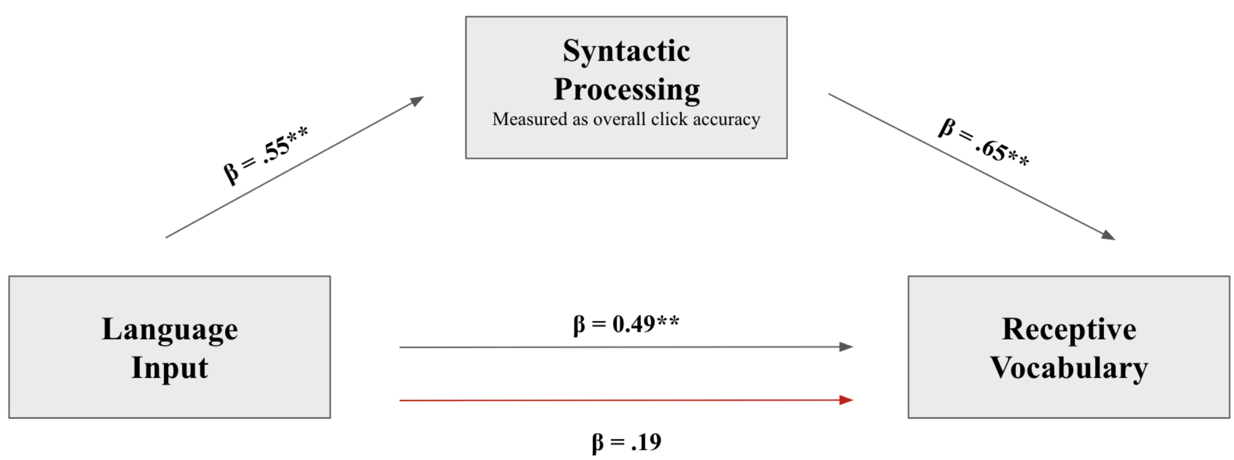


Fig. 6. This mediation model shows the effect of home language input on vocabulary size as mediated by syntactic processing (operationalized by overall click accuracy). The black and red arrows show results when the mediator was not included and was included in the model, respectively. Effects are marked with * if $p < .05$ and ** if $p < .01$.

4. Discussion

The present study investigated whether syntactic processing serves as a mechanism that links SES-related differences in home language exposure to receptive vocabulary in school-aged children. We found that syntactic processing (when measured through action data) was consistently associated with adult language input and vocabulary knowledge, while eye-movement data showed more variable patterns. Regardless, its role as an important component of language development as children age and enter increasingly complex language environments is supported by the present findings. Importantly, regression analyses and mediation analyses indicated that syntactic processing, when measured as overall click accuracy, explained a substantial portion of variance in receptive vocabulary and reduced the direct effect of home language input, suggesting that syntactic processing is both associated with language exposure and may serve as a key mechanism through which such exposure influences vocabulary acquisition.

Consistent with prior research (e.g., Weisleder & Fernald, 2013), higher-SES families were found to provide significantly more language input than their lower-SES counterparts, as measured by adult word count. Although SES differences in receptive vocabulary scores were not found to be statistically significant, the effect approaches significance, aligning with literature demonstrating SES-related disparities in children’s vocabulary (e.g., Rowe & Goldin-Meadow, 2009). A possible explanation for this weaker effect is that school-aged children are exposed to new and diverse language at schools, before- or after-school programs, or through internet access, decreasing the SES gap. Despite marginal SES differences in vocabulary, stronger SES differences were observed in language input and syntactic processing measures.

SES-differences were most strongly highlighted in the overall action accuracy measure of syntactic processing. Children who heard more adult speech at home were more successful at interpreting passive constructions, including those requiring revision of an initial agent-first misinterpretation. Higher-SES children were overall more accurate in identifying (clicking on) the target in the syntactic processing task, but group differences in eye-movement measures were inconsistent and did not reach statistical significance, limiting conclusions about real-time processing differences. This is likely attributable to the complexity of what eye-movements represent, as they are a result of interactions between language processing, visual information, memory, task demands, and the physical environment (Magnuson, 2019). For children, this may mean that eye movements are especially reflective of confounding factors such as quick attention shifts, physical state, and distractions in addition to the novel word learning process. Further instability may be explained by varying testing environments, the computerized language-learning task, and fatigue. Regardless, real-time processing efficiency may reflect cumulative exposure to language and may still be sensitive to differences in language input.

Syntactic processing was found to be strongly associated with receptive vocabulary, as children who performed better in the language processing task (as measured by action data) also demonstrated higher PPVT-5 scores. This supports the hypothesis that processing efficiency may support vocabulary acquisition by enabling children to utilize skills like scaffolding and word segmentation to decipher meaning of novel words and grammatical structures. Regression analyses demonstrating that syntactic processing measures, in particular overall click accuracy, were strong predictors of receptive vocabulary and reduced the effect of home language input when included in the same model, support this interpretation.

We ran complex models to see if either type of syntactic processing data, action-based or eye-movement measures, explained more variance in receptive vocabulary when paired with home language input compared to the base model of only home language input predicting receptive vocabulary. Of the models, we found that overall click accuracy, a measure of offline sentence comprehension, approached significance, suggesting that it plays a role in the relationship between language input and vocabulary development. We also found that looks to target in the passive without revision condition significantly explained more variance than the base model. In conjunction with our earlier finding on SES effects in this measure, these findings suggest that different aspects of syntactic processing (e.g., initial interpretation vs revision) contribute differently to vocabulary development.

A bootstrapped causal mediation analysis provided evidence to support syntactic processing acting as a linking mechanism between home language input and vocabulary outcomes. Because the effect of home language input on receptive vocabulary after controlling for syntactic processing was not significant, syntactic processing is suggested to be responsible for a significant proportion of the association between the two variables. Not only does this support previous literature (e.g., Weisleder & Fernald, 2013) suggesting that processing efficiency is a key mechanism linking home language exposure and expressive vocabulary in infants and toddlers, but it also demonstrates that this relationship between the three continues in school-aged children.

The observed correlations among home language input, syntactic processing, and vocabulary support the hypothesis that syntactic processing may be a mechanism linking language input to vocabulary outcomes. This pattern mirrors findings by Weisleder & Fernald (2013), extending their study from infancy into school-aged years and demonstrating that processing efficiency remains a relevant mechanism as language environments become more complex. These findings suggest that language exposure does not just contribute to vocabulary growth, but may also shape children's ability to efficiently parse and interpret complex syntactic structures in real time–however, evidence from eye-movement data in the current study was less consistent.

The project contributes to the current literature by exploring whether established language disparities persist in an underexplored population: school-aged children. School-aged children may be particularly sensitive to SES-related disparities in home language input, affecting their receptive vocabulary and syntactic processing, because of the new and complex language demands that unfold in their accumulating language environments. The present findings support this hypothesis, as SES-related differences were more robustly demonstrated in language input and syntactic processing than in vocabulary–perhaps disparities in syntactic processing persist even when vocabulary gaps begin to narrow. Additionally, by focusing on syntax, an underrepresented realm of language development, this study highlights the importance of investigating the dynamic processes that are key to language acquisition.

Current standardized language assessments lack precise tools for measuring syntax in this particular age group. This project gathers evidence to help establish a standardized assessment of sentence processing and syntactic development for school-aged children, which is essential for identifying those with or at risk for developmental language disorders. Additionally, these findings are useful in informing early language intervention strategy and policy for optimal language outcomes to reduce and eliminate SES-related academic gaps in both public and private school sectors. The data provides insight into how children process language structures; it may also be useful in developing clinical strategies for speech-language pathologists and teachers that effectively target and treat delays or disorders in syntactic development.

The study's participants did not reflect an even split in SES-groups; there were over twice the amount of children in the higher-SES group compared to the lower-SES group, limiting the generalizability of the study's findings. The split between boys and girls (24 males; 13 females) does not represent the population of school-aged children, either. The average income ($129,729) is high compared to the mean income of the DMV area and greater United States of America. Additionally, some participants did not have trials of each of the syntactic processing conditions and measures, which limits statistical power and may account for smaller effect sizes. We recognize that adult word count is an imperfect measure of language environment, as it captures quantity but not syntactic complexity or interaction quality of speech. PPVT-5 standardized scores are also not completely reflective of the full scope of the receptive vocabulary of an individual.

Future work should incorporate more holistic and potentially qualitative measures of language input, receptive vocabulary, and SES For example, measuring language input in terms of number of unique syntactic structures, turn-taking, or caregiver responsiveness would better capture language input and syntactic diversity as a whole. As this is not a category of metric that is currently calculated by the LENA system, development of such measures is necessary to gain more robust representations of the home language environment. Receptive vocabulary is not the full picture of a child's lexicon; thus, utilizing a composite measure of receptive and expressive vocabulary may also be informative in providing a more comprehensive profile. Lastly, SES was measured through family income alone, and it is recommended to use multiple measures (e.g., maternal level of education, income, occupation, etc.) to describe and operationalize SES.

Additionally, utilizing longitudinal study designs may provide additional insight into how changes in language input, syntactic processing, and vocabulary persist in children as they age. Expanding the sample to include more socioeconomically diverse and representative populations is critical for improving the generalizability of findings.

Despite these limitations, this study's findings suggest that syntactic processing efficiency is a meaningful and promising mechanism through which SES-related differences in language input influence vocabulary development. These results underscore the importance of examining language development not only through the lens of vocabulary, but also through real-time processing, which supports language-learning and comprehension. By extending this framework to school-aged children, the current study highlights the enduring role of processing efficiency in language learning across development and socioeconomic contexts. Focusing on syntactic parsing as a bridge between language input and vocabulary outcomes in school-aged children provided new insights into the effects of language exposure across development and socioeconomic contexts. Future research incorporating multiple or qualitative measures of language input and vocabulary will be essential to fortifying these findings and informing interventions and reliable tools for supporting and assessing syntactic processing in school-aged children.

5. Conclusion

The present study provides evidence that syntactic processing links home language input to receptive vocabulary in school-aged children. SES effects were seen more marginally in receptive vocabulary, but more robustly in home language exposure and syntactic processing, suggesting that processing may act as a key mechanism through which language environment differences shape linguistic outcomes. Additionally, mediation analyses revealed that syntactic processing accounted for a significant amount of the effect of home language input on receptive vocabulary. We extend prior work on syntactic processing by underscoring the continued impact of real-time processing mechanisms beyond early childhood. Understanding how school-aged children interpret and integrate complex syntactic information in real-time is essential in informing educational practice and clinical intervention, particularly in efforts to reduce SES-related disparities in language and academic achievement and to address developmental language disorders in this population.

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