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Vocabulary knowledge and reading comprehension account for SES-differences in how school-aged children infer word meanings from sentences

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ABSTRACT
Socioeconomic status (SES)-related language gaps are known to widen throughout the course of the school years; however, not all children from lower SES homes perform worse than their higher SES peers on measures of language. The current study uses mediation and moderated mediation to examine how cognitive and language abilities (vocabulary, reading, phonological processing, working memory) account for individual differences in children's ability to infer a novel word's meaning, a key component in word learning, in school-aged children from varying SES backgrounds. Vocabulary and reading comprehension mediated the relationship between SES and accuracy when inferring word meanings. The relationship between SES, vocabulary, and inferring word meaning was moderated by age, such that the influence of vocabulary on task performance was strongest in young children. The reading pathway did not interact with age effects, indicating reading is an important contributor to SES-related differences in how children infer a word's meaning throughout grade school. These findings highlight different paths by which children's trajectories for inferring word meanings may be impacted.

Introduction

School-age children learn up to 3,000 new words each year (Larsen & Nippold, 2007). An integral step in the word learning process is inferring the meaning of a new word using contextual cues, such as visual cues or linguistic information (Larsen & Nippold, 2007). The process of inferring a word's meaning changes as children get older and are exposed to less visual context-bound information, such as picture referents for new words, and instead must rely on linguistic information to identify the meaning of a new word. The process of using linguistic information to identify a word's meaning, referred to here as inferring word meaning, relies upon a learner's phonological processing skills, working memory, vocabulary knowledge, and reading comprehension, among other skills (Hill et al., 2017; Maguire et al., 2018; Hill & Wagovich, 2020). However, what results in successful inference of a word's meaning may vary for children from different socioeconomic backgrounds at different points in development (Frishkoff et al., 2008; Rowe & Goldin-Meadow, 2009; Spencer & Schuele, 2012; Weisleder & Fernald, 2013). At this time little is known about how children infer word meanings throughout the school years, how this skill varies across children from diverse backgrounds, and what mechanisms account for differences in how words are inferred. To address these questions, the current study examines which cognitive and linguistic

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attributes account for SES-based differences in how children infer new word meanings during the school years, and whether these attributes vary in their relevance at different points in development.

Word learning and meaning inferencing have been shown to differ on the basis of age and SES as early as preschool. Levine and colleagues (Levine et al., 2020) revealed that, on average, syntax, vocabulary, and word learning are all delayed in preschool aged children from lower-SES homes as compared to preschool-aged children from mid- and higher-SES homes. Across all language components, a main effect of age revealed that older children performed better than younger children and a main effect of SES revealed that children from higher-SES homes performed better than children from lower-SES homes. Although no interaction between age, SES, and language component emerged, visual inspection of the data suggests that early developmental differences across SES strata may be emerging. Similarly, Fernald et al. (2013) reported SES-based differences in vocabulary knowledge from 18 to 24 months but did not uncover a reliable interaction between SES and age for language processing efficiency. However, the authors stated that differences in processing efficiency between children from lower- and higher-SES homes at 18 and 24 months were substantial, with 24-month-old lower-SES children performing similar to their higher-SES peers at 18 months. While these studies inform us of group-related SES developmental differences, they do not capture substantial individual differences in language ability within and across SES. The current study adds to these studies by taking an individual differences approach to understanding how SES and age contribute to accuracy when inferring new word meanings.

Longitudinal research indicates that these group-related SES developmental differences in language processing efficiency and word learning, which emerge in preschool, can be attributed in part to differences in the early home environment. Thus, differences in the home environment may set children on a developmental trajectory where language outcomes differentially shape how they take advantage of language opportunities (Shavlik et al., 2020). For instance, the home language environment shapes children's vocabulary knowledge, reading comprehension, phonological processing, and working memory, across and within SES strata (Burchinal et al., 2020; Chiat & Polišenská, 2016; Dolean et al., 2019; Engel et al., 2008; Evans & Schamberg, 2009; Hoff, 2013; Hoff, 2003; Molfese et al., 2003; Rowe, 2012; Rowe & Weisleder, 2020). In school, these abilities are essential for acquiring new vocabulary (Cain et al., 2004; Hill et al., 2017; Maguire et al., 2018); thus, early individual differences in the home environment may lead to a cascading effect wherein difficulties with any number of these abilities negatively influence how children infer and learn new words. The current study tests this hypothesis by examining whether individual differences in language and cognitive abilities (i.e., phonological processing, working memory, vocabulary knowledge, reading comprehension) account for differences in how school-age children from diverse SES backgrounds infer the meaning of novel words.

Despite reports indicating that SES differences in inferring word meaning exist during the school years (Ralph et al., 2020; Maguire et al., 2018), little research has explored the path by which developmental differences in this skill emerge within and across SES strata. Using mediation analyses, Maguire et al. (2018) reported that vocabulary knowledge was the pathway by which SES was associated with inferring word meaning. Thus, SES in and of itself is not the causal mechanism for differences in inferring word meaning during the school years. Instead, differences in the early environments of children may exert their influence on vocabulary knowledge, in turn limiting their ability to infer new words and add to their vocabulary. It remains unknown whether this reciprocal relationship between existing language knowledge and the subsequent language learning process leads to the widening of language gaps between SES groups during the school years. To address this question, the current study examines how the strength of the effect of SES on inferring word meanings varies across the school years.

The first goal of this study is to take an individual differences approach to understanding SES-related differences in how children infer the meaning of novel words throughout the school years by using a cross-sectional sample of school-aged children. Based on the reciprocal effects of language learning, we predict that SES-related differences in performance on our inferring word meaning task will widen throughout the school years. The second goal of this study is to use mediation analyses to identify the role different abilities associated with inferring word meanings (i.e., phonological processing skills, working memory, vocabulary knowledge, and reading comprehension) may have in improving children's long-term ability to acquire robust word knowledge across SES. Similar to Maguire et al. (2018), we hypothesize that vocabulary knowledge will account for SES-related differences on the inferring word meaning task. Our third and final goal is to determine whether the attributes related to inferring word meaning vary in their importance at different developmental periods using conditional processes (i.e., moderated mediation). We predict that the pathways identified as significant in our mediation analysis will be significant for younger children, but not older children, promoting the importance of early intervention.

Method

Participants

Two-hundred and forty school-aged children (M_{age} = 137.73 months; SD_{age} = 26.46 months; Range = 96–191 months) successfully completed an experimental inferring word meaning task and a battery of language and cognitive measures intended to measure skills with known relationships with word learning (receptive vocabulary, reading comprehension, phonological working memory, working memory). We describe each of these measures in more detail below. Participants' EEG was recorded during completion of the inferring word meaning task; however, the current study focuses on the behavioral results from the task. Using the pwr.f2.test function from the pwr package (Cohen, 1988) of R (RStudio Team, 2020), we calculated the sample size necessary to execute multiple regression analyses with 5 variables of interest. The Cohen.ES function verified that a value of 0.15 represented the ability to detect medium effect sizes (Cohen, 1988). Using these medium effect sizes, with a significance level at 0.05, and power at 80%, we calculated the sample size necessary to execute our analysis at 86. We also used the ssMediation.VSMc function from the powerMediation package (Vittinghoff, Sen & McCulloch, 2009) of R to compute the sample size needed to reliably conduct a mediation analysis. Using the same power and effect size stated above, with the regression coefficient for the mediator set at .04, we calculated the sample size necessary to execute our analysis was 110. Therefore, we have sufficient power to conduct all subsequent analyses.

Given this study's interest in typical language development, all children had no history of language or developmental delay based on parental report. Parents self-reported their child's race and ethnicity (American Indian or Alaskan Native = 1; Asian = 18; Black = 17; White = 172; Multiple = 35; Other = 1; Did not declare = 3; 48.2% Hispanic or Latino). Parents gave written parental consent to participate and children provided written assent, all in accordance with the Institutional Review Board of the University of Texas at Dallas. This study was conducted according to the Good Clinical Practice Guidelines, the Declaration of Helsinki, and the U.S. Code of Federal Regulations. Parents and children received a $50 gift card for their participation.

Procedure

Parents completed a questionnaire in which they reported primary caregivers' educational level, children's race and ethnicity, date of birth, history of neurological or developmental disorders, bilingual language exposure, and home environment. Children then completed the battery of language and cognitive assessments. Children's ability to infer words from linguistic context were assessed using a novel inferring word meaning paradigm, described in more detail below (A.D. Abel et al., 2018; Alyson D. Abel et al., 2020; Maguire et al., 2018; Ralph et al., 2020).

Socioeconomic status

SES was determined based on parental self-report of maternal educational attainment. While research has used multiple separate indicators, a composite index, or just one single scale to quantify SES, the most often-used, single-scale indicator in child development research has been maternal education (Bornstein et al., 2003; Campbell et al., 2003; DeGarmo et al., 1999; Dollaghan et al., 1999; Ensminger & Fothergill, 2014; Hoff et al., 2011; Hoffman, 2003; Richels & Johnson, 2013). Likewise, longitudinal research studies have reported that maternal education is the most consistent predictor of child language outcomes (Coleman, 1966; Jackson et al., 2017). Following this, we coded maternal educational attainment in five levels for the current analysis: 0 = less than high school (9th grade), 1 = high school graduate (GED or diploma), 2 = some college (including an Associate's degree), 3 = college graduate, 4 = graduate degree. The total number of participants in each level can be found in Table 1.

Bilingual language exposure

The current research was conducted in Dallas County, where 53% of the child population is of Hispanic or Latino descent and 43.9% of the population speaks a language other than English (American Community Survey, United States Census, 2019). Our sample is representative of this population, as 49.6% of parents (N = 119) reported their child as Hispanic or Latino descent, and 43.8% (N = 105) reported their child as bilingual. In subsequent analyses, bilingual language exposure was included as a categorical variable: children were either bilingual (N = 105) or monolingual (N = 135). More detailed information related to how bilingual language exposure varied across SES strata can be found in Table 1, including a one-way ANOVA showing that there were significantly more bilingual children in lower-SES groups than higher-SES groups. In all subsequent analyses, bilingual language exposure was effect coded so that Monolingual = 0 and Bilingual = 1.

Language and cognitive measures

Receptive vocabulary knowledge was tested using the Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4; Campbell & Dommestrup, 2010). On this task, children view four pictures and are presented with a word. They must then select the picture that best matches the word that they hear. Reading comprehension was measured using the Gray Oral Reading Tests–Fifth Edition comprehension sub-test (GORT-V comprehension; Hall & Tannebaum, 2013). In this task children answer questions based on passages that they read aloud. Working memory was measured using a Digit Span task, similar to those included in the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scales (WMS). In this task children listened to numbers and are asked to repeat the numbers back, in the order they hear them. Raw scores from all three assessments were log-transformed for subsequent analyses. Phonological memory was measured using a Nonword Repetition task (Dollaghan & Campbell, 1998). In this task, children listen to alternative consonant-vowel nonwords ranging from 1 to 4 syllables and are asked to repeat them back. Scores were calculated based on the percent of consonants accurately identified by children. These percentages were then log-transformed to include in subsequent analyses. One-way ANOVAs indicated that higher-SES children performed significantly better than children from lower-SES homes on all measures (see, Table 1).

Inferring word meaning task

The first step of word learning, inferring word meaning, was measured using the same behavioral and EEG paradigm that has previously been utilized in children (Alyson D. Abel et al., 2020; Ralph et al., 2020; A.D. Abel et al., 2018; Maguire et al., 2018). It was designed to reflect real-life examples where a child must infer the meaning of a novel word form for which they already have an existing semantic representation, and is similar to past word learning studies that taught children names for familiar objects (e.g., Fritz, Morris, Nolan, & Singleton, 2007). In this task, children read sentences which were presented one word at a time in black letters on a white screen that was approximately 1 meter away from them. Sentences were presented in triplets and each triplet ended with the same pseudoword. Children were instructed that they were going to read sets of three sentences, all of which ended with a

Table 1. Assessment performance across SES strata. All values are reported as mean (standard deviation).

Maternal Education	<9th grade	High School	Some College	College Degree	Graduate Degree	p-value
N	37	32	33	86	52	
Inferring Word Meaning (Percent Correct)	52 (20)	58 (18)	57 (22)	69 (20)	66 (19)	<0.001
Vocabulary (raw score)	151.27 (28.87)	157.69 (25.41)	167.42 (23.82)	179.51 (23.63)	181.9 (19.15)	<0.001
Working Memory (raw score)	8.08 (1.88)	7.06 (2.05)	8.12 (1.88)	8.98 (2.8)	8.65 (3.19)	0.007
Reading Comprehension (raw score)	29.28 (10.37)	27.87 (8.63)	31.75 (9.8)	40.78 (13.99)	40.61 (11.91)	<0.001
Phonological Memory (percent correct)	88 (9)	86 (10)	91 (7)	92 (6)	91 (7)	<0.001
Age in Months	138.27 (27.99)	141.25 (27.65)	133.48 (28.54)	138.69 (25.15)	133.38 (27.99)	0.611
Percent Bilingual	97 (16)	75 (44)	39 (50)	29 (51)	25 (48)	<0.001

made-up word. They were then told they would need to identify what real word could replace the made-up word across all three sentences (Meaning condition), but that sometimes they would not be able to come up with a real word that fit all three sentences (No Meaning). In the Meaning condition, cloze probability increased across the presentation of the three sentences which composed a triplet (for a complete list of stimuli see Appendix A or Maguire et al., 2018). The No Meaning condition served as a control condition for exposure and did not increase in cloze probability, nor did it support meaning acquisition. Only the Meaning condition is evaluated in the current study, but results related to the control condition may be found in A.D. Abel et al. (2018). Within the Meaning condition, children were expected to infer the semantic meaning of the pseudoword. After the presentation of all three sentences, a trained experimenter asked the child if the "made up word represented a real word, and if so, what word?." Responses were recorded and rated as correct or incorrect by two trained coders (interrater reliability was 96.8%). A "correct" response was counted as a) the "target" word that was intentionally designed to complete all three sentences, or b) a semantically plausible word that fit in all three sentences. Incorrect responses were any implausible word or no response. Average accuracy across trials was computed to determine an individual's overall accuracy when inferring word meaning.

Sentences were between 6 and 9 words in length. All of the words in the sentence were early-acquired, high-frequency words from well-established corpora (Carroll et al., 1971; Fenson et al., 1994) thus removing knowledge of the specific words in the sentence as a confound in studying the process of inferring a novel word's meaning. Participants were randomly assigned to one of eight randomized orders of 100 sentence triplets, 50 triplets per condition. For additional information on how the stimuli were created see, A.D. Abel et al. (2018). Participants completed a training session before the task, including two triplets from each condition, during which they received accuracy feedback. No feedback was provided during the task. Table 1 overviews average accuracy on this task across SES strata and the results from a one-way ANOVA indicate that children from lower SES homes performed worse than their higher SES peers on the inferring word meaning task.

Results

How does the strength of the effect of SES on inferring word meanings vary across the school years?

While group-related SES differences have been reported in how children infer word meaning during the school years (Ralph et al., 2020; Maguire et al., 2018), we suspect there are significant individual differences in this skill within SES across the course of development. Therefore, we took an individual differences approach, by using hierarchical logistic regression, to examine how the skill of inferring word meanings differs as a function of SES and age. Step 1 included fixed effects for child age in months, bilingual language exposure, gender, and SES in the model. Step 2 added an interaction term between SES and age in months. Across all models, SES was dummy coded, and age was mean centered. Accuracy on each trial of the inferring word meanings task (0 = incorrect, 1 = correct) served as the dependent variable, with random by-subject intercepts included.

In step 1, being older (age: $b = 0.02$, $S.E. = 0.001$, $p < .001$, $d = 0.54$, 95% CI [0.44, 0.64]) and coming from a higher SES home (college graduate: $b = 0.71$, $S.E. = 0.18$, $p < .001$, $d = 0.71$, 95% CI [0.36, 1.06]; graduate degree: $b = 0.71$, $S.E. = 0.20$, $p < .001$, $d = 0.71$, 95% CI [0.32, 1.09]) was more strongly associated with accurately inferring the novel words' meaning on any given trial. Although Step 2 did not significantly account for any additional variability ($X^2(4, 240) = 3.36$, $p = .50$), this step revealed SES differences remain stable across individuals aged 8–16 years, indicated by significant main effects of age and SES and non-significant interactions between each level of SES and child age (see, Table 2 for statistics and Figure 1 for visualization).

Table 2. Complete statistical output of hierarchical logistic regression between SES and age (Model 1) and bilingualism and age (Model 2). Intercept represents the Maternal Education reference group (less than high school (9th grade)). *** $p < .001$.

Included in both Models 1 and 2	**Step 1.**	**Estimate**	**Std. Error**	**p-value**
	Intercept	0.17	0.19	0.39
	Gender	0.18	0.11	0.09
	Bilingualism	−0.20	0.13	0.11
	Age in Months	0.02	0.002	< 2e-16 ***
	Maternal Education			
	HS Graduate	0.16	0.19	0.40
	Some College	0.29	0.21	0.16
	College Graduate	0.71	0.18	8.19e-05 ***
	Graduate Degree	0.71	0.20	3.40e-4 ***
Model 1. Interaction term between SES and Age.	**Step 2.**	**Estimate**	**Std. Error**	**p-value**
	Intercept	0.18	0.19	0.36
	Gender	0.18	0.11	0.10
	Bilingualism	−0.20	0.13	0.11
	Age in Months	0.02	0.005	2.12e-4 ***
	Maternal Education			
	HS Graduate	0.17	0.19	0.37
	Some College	0.28	0.21	0.18
	College Graduate	0.70	0.20	9.06e-5***
	Graduate Degree	0.69	0.20	4.23e-4***
	Interaction Terms			
	HS Graduate * Age	−0.001	0.007	0.89
	Some College * Age	0.001	0.007	0.91
	College Graduate * Age	0.008	0.006	0.18
	Graduate Degree * Age	0.001	0.006	0.88
Model 2. Interaction term between bilingualism and Age.	**Step 2.**	**Estimate**	**Std. Error**	**p-value**
	Intercept	0.17	0.19	0.39
	Gender	0.18	0.11	0.09
	Bilingualism	−0.20	0.13	0.11
	Age in Months	0.02	0.002	8.01e-15***
	Maternal Education			
	HS Graduate	0.16	0.19	0.40
	Some College	0.29	0.21	0.16
	College Graduate	0.71	0.18	8.78e-05 ***
	Graduate Degree	0.71	0.20	3.4e-4 ***
	Interaction Terms			
	Bilingualism* Age	−0.002	0.004	0.69

Differences in how children infer word meanings might also be influenced by bilingual language experience throughout the school years. Although the previous model statistically controlled for this variable, we ran a second model in which we asked how the effect of bilingual language experience on inferring word meaning varied across the school years. Using the same steps described above we found that, once again, SES and age independently predicted performance on the inferring word meaning task. However, differences in inferring word meaning across the school years were not attributed to bilingual language experience, indicated by the lack of main effect (b =0.01, $S.E.$ = 0.55, p = .98 d = 0.20, 95% CI [−0.45, 0.05]) and non-significant interaction between bilingualism and child age (b = −0.002, $S.E.$ = 0.004, p = .69, d = 0.04, 95% CI [−0.25, 0.*16*]; see, Table 2 for statistics and Figure 1 for visualization).

Which cognitive and linguistic attributes account for known SES gaps in the process of inferring word meanings during the school years?

Our third model utilized mediation to identify if differences in performance on the inferring word meaning task related to SES could be explained by vocabulary knowledge, reading comprehension, working memory, or phonological memory. We used the PROCESS macro (Hayes, 2013) to specify this parallel multiple mediator model with ordinary least squares path analysis (see, Figure 2). To

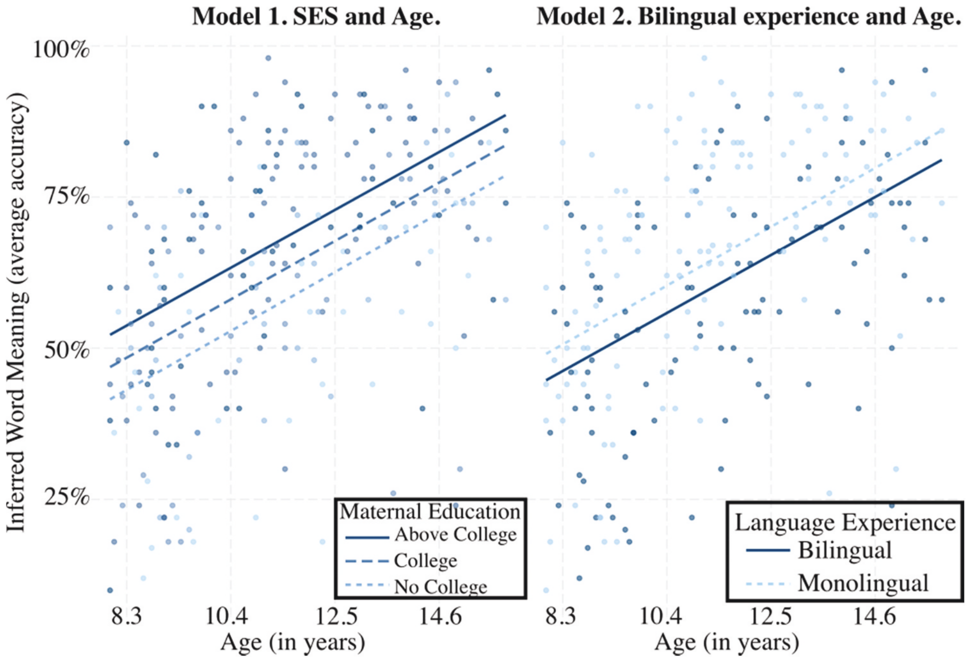

Figure 1. Age and SES are positively associated with average accuracy on the inferring word meaning task (Model 1). Age, but not bilingual language experience, was associated with average accuracy on the inferring word meaning task (Model 2). Although statistical models included accuracy on each trial, plots include average accuracy across trials for visualization purposes.

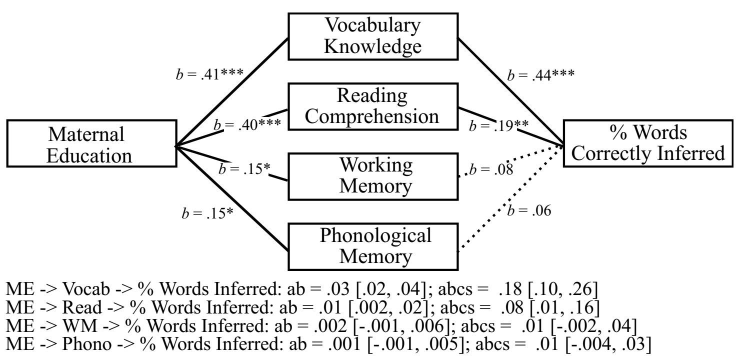

Figure 2. The association between SES and percent of words accurately inferred was mediated by vocabulary knowledge and reading comprehension, when controlling for bilingual language experience, gender, and age (Model 3). ab = unstandardized indirect effect; abcs = completely standardized indirect effect. The 95% confidence intervals for the indirect effects are contained in brackets after the point estimates and were constructed using bias-corrected bootstrapping with 5000 samples. * $p < .05$, ** $p < .01$, *** $p < .001$

ensure that demographic features (i.e., age, gender, and bilingual language exposure) did not provide an alternative explanation for the effects of SES (operationalized as maternal education) on the outcomes, we controlled for these variables in the multiple mediation analysis. Performance on the inferring word meaning task was calculated as mean accuracy across all 50 trials per participant. Indirect effects for the specific pathways were computed (labeled "ab" in Figure 2) using bias-corrected bootstrapping with 5,000 samples to construct 95% confidence intervals. Intervals not containing zero indicate that the indirect effect is statistically significant. Completely standardized indirect effects were computed (labeled "abcs" in Figure 2) to obtain measures of effect size (Preacher & Hayes, 2008); values of |.01|, |.09|, and |.25| are considered small, medium, and large effects, respectively.

Similar to Maguire et al. (2018), the Maternal Education-to-Vocabulary Knowledge-to-Percent Words Inferred pathway emerged as significant (ab: b = 0.03, boot $S.E.$ = 0.01, boot 95% CI [.02, .04]; abcs: B = 0.18, boot $S.E.$ = 0.04, boot 95% CI [.10, .26]). The Maternal Education-to-Reading Comprehension-to-Percent Words Inferred pathway also emerged as significant (ab: b = 0.01, boot $S.E.$ = 0.01, boot 95% CI [.002, .02]; abcs: B = 0.08, boot $S.E.$ = 0.04, boot 95% CI [.01, .16]). The completely standardized indirect effect for vocabulary knowledge and reading comprehension were .18 and .08, respectively, indicating that both are important mechanisms by which maternal education relates to inferring the meaning of novel words.

At what age(s) will modifying the mechanisms identified in the previous analysis, result in the greatest gains when inferring word meanings?

Model 4 sought to determine whether the pathways identified as significant in the last analysis varied across ages. Given that both vocabulary knowledge and reading comprehension represent modifiable mechanisms accounting for the association between SES and inferring word meaning, it is of critical importance that we pinpoint the ages when modifying these mechanisms will result in the greatest gains. Conditional processes, also known as moderated mediation, were implemented to identify if either the Maternal Education-to-Vocabulary Knowledge-to-Percent Words Inferred pathway or the Maternal Education-to-Reading Comprehension-to-Percent Words Inferred pathway were moderated by child age in years. We used the PROCESS macro (Hayes, 2013) to specify this moderated mediation model (using model 14; see, Figure 3). To ensure that demographic features (i.e., gender, bilingual language exposure) and other attributes which were not significant in previous models (i.e., phonological memory, working memory) did not provide an alternative explanation for the effects of age on the outcome, we controlled for these variables in the analysis. Once again, bias-corrected bootstrapping with 5,000 samples was implemented to construct 95% confidence intervals for the indirect effects. Intervals not containing zero indicate that the indirect effect is regarded as statistically significant.

While both the Maternal Education-to-Vocabulary Knowledge-to-Percent Words Inferred and Maternal Education-to-Reading Comprehension-to-Percent Words Inferred pathways significantly varied across ages, the index of moderated mediation was only significant for the Vocabulary Knowledge pathway ($Index$ = −0.004, boot $S.E.$ = 0.002, 95% CI [−.009, −.003]). The bootstrapped confidence intervals of the conditional effects indicated that the mediation pathway was moderated by age for children age 11 and younger (boot 95% CI [.02, .05]), but not beyond that age (boot 95% CI [−.01, .03]). Thus, vocabulary knowledge accounts for SES-related gaps in inferring word meaning for children under 11 years of age.

The bootstrapped confidence intervals of the conditional effects for the Maternal Education-to-Reading Comprehension-to-Percent Words Inferred pathway, indicated children older than 11 years old may benefit most from improved reading comprehension abilities (boot 95% CI [.004, .03]).

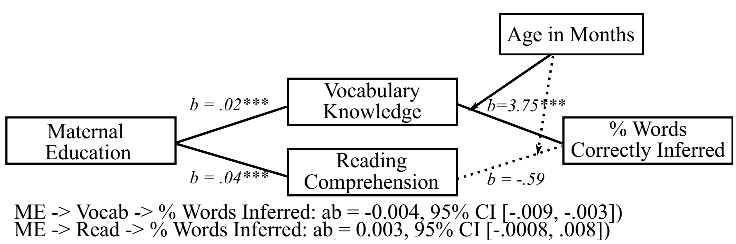

Figure 3. The SES to Vocabulary knowledge to Percent words correctly inferred pathway varies significantly depending on the child's age (Model 4). Specifically, this mediation pathway was moderated by age for children younger than 11 years old. The 95% confidence intervals for the indirect effects were constructed using bias-corrected bootstrapping with 5000 samples. *** p < .001.

However, because the index of moderated mediation confidence interval included zero (*Index* = 0.003, boot *S.E.* = 0.002, boot 95% CI [−.0008, .008]), we cannot confidently state that this mediated pathway is moderated by age.

Since it is possible that bilingual language exposure may interact with either of these pathways, we included it as a moderator of both mediator pathways in Model 5. Similar to the previous analysis, we controlled for demographic features (i.e., gender, age in years) and other attributes which were not significant in previous models (i.e., phonological memory, working memory). Bilingual language exposure did not moderate either the Maternal Education-to-Vocabulary Knowledge-to-Percent Words Inferred pathway (*Index* = −.02, boot *S.E.* = 0.01, boot 95% CI [−.04, .000]), nor the Maternal Education-to-Reading Comprehension-to-Percent Words Inferred pathway (*Index* = 0.02, *S.E.* = 0.01, 95% CI [−.003, .04]).

Discussion

The current study sought to clarify the role that cognitive and language abilities have on SES-related individual differences in how children infer word meaning across the school years. At the group level, children from lower-SES homes performed more poorly than their higher-SES peers on the inferring word meaning task; however, SES did not explain a significant portion of unique variance in performance. Rather, vocabulary knowledge and reading comprehension mediate this effect during the school years. These findings echo earlier longitudinal studies of word learning in preschoolers, indicating SES does not determine a child's likelihood of being able to accurately infer the meaning of new words, but that early life experiences may differentially shape the skills children have available for taking advantage of learning opportunities (Sabbagh & Henderson, 2013; Shavlik et al., 2020). The relevance and implications of these findings for intervention research are discussed below.

Although there is a great deal of variability between children, vocabulary knowledge, reading comprehension and word inferencing have been shown to differ across SES, with strong, consistent evidence that differences in the home language environment underlie these effects (Levine et al., 2020; Luo et al., 2021; Schwab & Lew-Williams, 2016; Spencer & Schuele, 2012; Weisleder & Fernald, 2013). Our results extend these findings to school-aged children and emphasize the benefit that strong vocabulary knowledge and reading comprehension skills can have upon the ability to infer word meanings. The reason that vocabulary knowledge is likely so important to inferring word meanings is that possessing deeper semantic knowledge eases semantic integration during sentence processing, allowing for children to make better predictions about what will come next in the sentence (Luo et al., 2021; Maguire et al., 2018; Cain et al., 2004; Weisleder & Fernald, 2013). Importantly though, this association was only significant for children under 11 years of age. Thus, early interventions on vocabulary knowledge may yield positive gains for the early stages of word learning when a child must infer the meaning of new words. Children of all ages showed a strong association between reading comprehension and their ability to infer new word meanings in the current study. This is vitally important as reading is the only school readiness domain that predicts more rapid acquisition of academic and social skills throughout grade school (Pace et al., 2019). Thus, interventions targeting reading comprehension may lead to greater gains in how children infer word meanings at any time during the school years.

It is also likely that vocabulary exposure and reading comprehension reciprocally influence one another to aid in how children infer new word meanings (e.g., the reciprocal hypothesis; Nagy et al., 2012; Stanovich & Cunningham, 1993; Wagner & Meros, 2010). As children read more, they are exposed to more words and knowledge, in turn exposing them to more opportunities to infer word meanings and develop vocabulary knowledge. Some researchers therefore advocate that vocabulary interventions provide rich language learning environments with opportunities for exposure to novel words in written discourses (Stahl & Nagy, 2005; for review, see, Elleman et al., 2019). Based on the reciprocal hypothesis, interventions focused on vocabulary could have a "trickle down" effect, ultimately benefitting both reading comprehension and the ability to infer new word meanings for children from lower-SES homes. These interventions typically focus on exposure to novel words in written contexts, yet our findings advocate for the utility of inferring word meanings in auditory contexts especially for children who struggle with reading comprehension. Given that children from lower-SES homes performed lower than their higher-SES peers on measures of reading comprehension and word inferencing in written contexts, targeting vocabulary through audiobooks or other auditory platforms may lead to greater gains in subsequent vocabulary.

One reason that gaps in the number of word meanings children inferred from context may not have grown during the school years, as we predicted, could be attributed to the simplicity of the task. All words to be inferred were concrete nouns with an age of acquisition of 2.5 years or younger, and all sentences were designed for a 6-year-old to understand (i.e., simple syntax, early acquired vocabulary). The fact that our sentences were relatively simple emphasizes the lack of difference in performance between older children from lower- and higher-SES groups. Older children should have had no difficulty on this task compared to younger children and, subsequently, gaps in performance should have shrunk. Counter to this hypothesis, we observed stable differences, suggesting true gaps in how children infer new word meanings may widen during the school years. To address this question, future studies should adapt the demands of their word inferencing tasks on the basis of age.

Limitations

The current sample was highly representative of the larger population from which it was drawn; however, one limitation of the current study was that children from lower-SES homes were on average more likely to be bilingual than children from higher-SES homes. A lack of significant effect of bilingualism may therefore be attributed collinearity between bilingualism and SES in the current sample. While we did statistically control for bilingual language exposure in all models, and bilingualism never emerged as a significant predictor of performance on the word inferencing task, it should not be overlooked as having a role in how these children infer new word meanings. Figure 1 emphasizes the degree of individual variability in task performance between monolingual and bilingual children. It appears that for many, but not all bilingual children, performance on this task was poorer than their monolingual peers. This is problematic, as all children in the current study attended schools where instructions and learning occur in English. Thus, we believe our findings still have important implications for differences in how monolingual and bilingual children infer new word meanings in school and point to vocabulary knowledge as a possible mediator for these differences.

Although other studies of word learning have utilized similar paradigms by teaching children names for familiar objects (e.g., Fritz, Morris, Nolan, & Singleton, 2007), our inferring word meaning task is only capturing one step in the process of learning a new word. Abel et al. (2020) implemented the same inferring word meaning paradigm utilized in the current study but added a word form recognition task to evaluate whether children could identify the nonwords whose meanings they inferred from context. EEG was recorded as participants completed both tasks. Behavioral data from the recognition task indicated that children were unable to explicitly identify the nonsense word forms they had previously encountered in the inferring word meaning task. However, EEG data, also from the recognition task, revealed differences in neural processing between nonwords with meanings previously inferred and nonwords with no meanings inferred. Taken together, these findings indicate that successfully inferring the meaning of a word in the current task does not necessarily translate to explicit learning of word form but there is some level of implicit word form recognition. Given that the current study utilizes the same inferring word meaning paradigm, we can extrapolate that our findings relate only to inferring meaning but do not directly translate to word learning success. Future research should develop tasks which measure all aspects of learning a new word using only the surrounding information.

Perhaps the most important lesson to be learned from this study is that substantial individual variability exists in how children infer word meanings during the school years. Past research emphasizes significant differences in language outcomes between groups on the basis of SES (Fernald et al., 2013; Hart & Risley, 1995; Hoff, 2006); however, the current findings add evidence to research promoting the heterogeneity of language skills within SES samples (Hirsh-Pasek et al., 2015; Masek et al., 2021). While some children from lower-SES homes demonstrated difficulty on the current inferring word meaning task, despite the task containing only words that should have already been known by the children, the task was relatively easy for lower-SES children who possessed greater vocabulary knowledge and stronger reading comprehension skills. By utilizing a simpler task, the current study was able to pinpoint how existing language abilities, such as vocabulary knowledge and reading comprehension, account for SES-related differences in how children infer new word meanings. Taken together, the current findings suggest that interventions aimed at vocabulary knowledge could systematically benefit young children from lower SES-homes who struggle with the early stages of inferring new words from written contexts.

Disclosure statement

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. All scripts used to conduct analyses are publicly available on Github at: https://github.com/juliagoolia28/manuscripts/tree/master/LLD_vocab_reading_mediation

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Appendix A. Sentence stimuli

Triplet Number	Sentences	Nonword List 1	Nonword List 2	Nonword List 3
1	At lunch she didn't eat her apple At the store, buy an apple Snow White snacked on an apple	laig	kuth	goz
2	They can sit on the chairs or on the couch He watched TV from the couch He watched TV while sitting on the couch	vush	noib	joon
3	Her parents bought her a bed The sick child spent the day in his bed Mom piled the pillows on the bed	thov	yaj	kouf
4	The mean boy hid her book While studying, she fell asleep on her book On rainy days, I like to read a book	vosh	lev	wooth
5	The bird pooped on my car My brother let me borrow his car I like to drive my car	gime	teib	nuk
6	Each morning, they walk to their school I sold candy for money for my school She is in the biggest class at her school	lesh	vave	maich
7	Don't forget where you put your cup My drink spilled when I knocked over my cup Pour some water in my cup	raub	pouk	yeb
8	The door was protected by a dog I used to be afraid of her dog Get the leash out for the dog	boit	beel	daep
9	The nasty bug flew into his ear The doctor looked into her ear The headphones go in your ear	keet	haum	therg
10	He looks just like you in the face Those twins look different in the face She wears a lot of makeup on her face	pieg	looz	booj
11	I forgot to bring home my food I hope she will share her food The dog ate all his food	vaip	gen	wesh
12	Her favorite stuffed animal is a frog A toad is smaller than a frog My favorite amphibian is the frog	kawn	geb	yez
13	That bird balances on her legs To learn to swim, you must kick your legs Those jeans are too short for her legs	foug	tooj	teep
14	I like that poster for the movie He has never seen the movie The theater is showing a movie	guz	zeem	fef
15	He needs to wash his pants I'm too tall to wear her pants Tuck your shirt into your pants	lal	loing	vud
16	Every summer, I spend time at the pool She went swimming at the pool He grabbed his swimsuit and headed to the pool	kois	kob	jaf
17	The baker is famous for his bread I make my sandwiches with the bread At the bakery, get a loaf of the bread	leet	yab	toth

(*Continued*)

Triplet Number	Sentences	Nonword List 1	Nonword List 2	Nonword List 3
18	I wash my dogs in the shower If you're dirty, take a shower He smelled bad, so he took a shower	fawz	reet	werg
19	Be sure to stay out of the sun It's too hot to stay in the sun Some glasses protect your eyes from the sun	reesh	thaep	kern
20	For my birthday I got a TV She saw that movie at home on her TV We watched the show on her TV	bez	kais	jeng
21	I asked you to wash the blanket The baby likes to sleep with her blanket To stay warm, I snuggle under the blanket	jurg	toud	taz
22	While baking, she burned her arm When she was scared, she grabbed his arm He fell off the tree and broke his arm	bawv	jawch	jawsh
23	My fingers wrinkle in the bath I like to put bubbles in my bath The muddy dog really needs a bath	zuv	kaj	baab
24	My favorite type of pet is a bird The cat looked out the window watching the bird The car window was pooped on by the bird	persh	daib	kersh
25	You can't go out without a shirt I do not like his shirt Be sure to tuck in your shirt	paus	vath	nauk
26	Go outside and play with the cat I'm covered with hair from the cat All night, I heard the meowing of a cat	tawd	thum	paug
27	She played with the doll more than the ball She packed the snow into a ball My dog loves to fetch the ball	naz	pauv	veeg
28	She is taking advice from her doctor He needs to go see his doctor When he feels sick, he visits the doctor	jep	jaed	miv
29	He plans to repaint his door I could hear them fighting through the door When you leave, be sure to lock the door	kis	nouch	pite
30	I've got something in my eye The doctor shined the light in her eye The eye patch covers her eye	hig	thuf	neg
31	He has a wart on his foot The lamp fell on her foot Cinderella's shoe fit on her foot	theesh	duth	zut
32	Don't go outside without your hat Most sunny days I like to wear a hat The baseball player always wears a hat	chab	puz	boub
33	Her Halloween costume was a lion At the zoo, the tiger was beside the lion The king of the jungle is the lion	naug	thup	wone
34	It gets hot when we turn on the oven Dinner is cooking in the oven She baked the cookies in the oven	kerd	bown	toob
35	I like the pattern on the plate There is too much on your plate He ate everything on his plate	chun	wus	geth
36	Over the summer, she grew out of her coat Don't go in the snow without your coat When she came in, she hung up her coat	kawsh	pawv	naf
37	Before coming inside, please wipe off your shoes If you go outside, put on your shoes The child learned how to tie his shoes	wob	reb	koob
38	I can't eat lunch because I forgot my spoon The toddler can't eat with a spoon You need to stir the soup with a spoon	tez	hek	thoos

(*Continued*)

Triplet Number	Sentences	Nonword List 1	Nonword List 2	Nonword List 3
39	In our backyard there is a tree During the storm, the lightning struck the tree The strong man chopped down the tree	ruch	vod	keek
40	He loaned his friend his bicycle He took a ride on her bicycle He taught his son how to ride a bicycle	theig	kaub	huth
41	After dinner I will eat my candy Don't eat all of the candy After Halloween, she eats all of her candy	laeb	dag	moob
42	The big cat is the mom The puppy is looking for its mom The baby loves to be with her mom	powf	muz	nup
43	I broke a leg on the chair I want to sit in that chair Join the group and pull up a chair	chath	nerz	theek
44	The dog dug up and ruined a flower For the dance, he gave her a flower Her perfume smelled like a flower	pos	lieb	mook
45	My windshield was hit by a bug Jake wants to squish the bug I think I just swallowed a bug	bok	hep	waich
46	I will fight you with my pillow My brother doesn't like to sleep with a pillow There were feathers stuffed inside my pillow	joog	thej	dawch
47	They were late so they missed their plane The passengers got on the plane We traveled to Europe on a plane	bov	zub	koov
48	The girl tripped over the stairs I heard footsteps on the stairs The elevator is faster than the stairs	douj	neth	naen
49	Mom spent time cleaning her table He stood up on the table The dinner is on the table	lav	rauch	douth
50	She played games with the teacher Class was dismissed by the teacher Homework is assigned by the teacher	keeb	dooth	moog