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Maternal Socioeconomic Status Influences the Range of Expectations During Language Comprehension in Adulthood

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Abstract

In infancy, maternal socioeconomic status (SES) is associated with real-time language processing skills, but whether or not (and if so, how) this relationship carries into adulthood is unknown. We explored the effects of maternal SES in college-aged adults on eye-tracked, spoken sentence comprehension tasks using the visual world paradigm. When sentences ended in highly plausible, expected target nouns (Exp. 1), higher SES was associated with a greater likelihood of considering alternative endings related to the action of the sentence. Moreover, for unexpected sentence endings (Exp. 2), individuals from higher SES backgrounds were sensitive to whether the ending was action-related (plausible) or unrelated (implausible), showing a benefit for plausible endings. Individuals from lower SES backgrounds did not show this advantage. This suggests maternal SES can influence the dynamics of sentence processing even in adulthood, with consequences for processing unexpected content. These findings highlight the importance of early lexical experience for adult language skills.

Keywords: Sentence processing; Anticipatory language processing; Language comprehension; Eye-tracking; Visual world paradigm; Individual differences; Socioeconomic status; Language development

1. Introduction

Language comprehension involves rapid updating of mental states in response to an unfolding speech signal and is influenced by a host of variables, including properties of both the language and the comprehender. Individual differences in linguistic experiences

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can have important consequences for language comprehension, with growing evidence that the quantity and quality of early parental language input influences real-time language processing in children (Fernald, Marchman, & Weisleder, 2012; Weisleder & Fernald, 2013). We explore the claim that broad differences in linguistic experiences during childhood, inferred from a measure of an individual's maternal socioeconomic status, can influence language comprehension into adulthood. In particular, we ask whether the speed and dynamics of anticipatory language processing in college-aged young adults associate with maternal socioeconomic status (SES).

Experience-related differences in language skills, particularly in vocabulary, are well-documented in the early stages of life (Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991), and these differences are linked to subsequent trajectories of language growth and academic skills throughout primary and secondary school (Alexander, Entwisle, & Horsey, 1997; Durham, Farkas, Hammer, Tomblin, & Catts, 2007). More recently, researchers have noted that experiential differences (including vocabulary size, amount of parental language input, and SES) are also linked to real-time language comprehension. For example, *speed* of real-time language processing in children is influenced by individual differences in linguistic experience tied to the quantity of parental speech (Fernald et al., 2012; Weisleder & Fernald, 2013). In turn, the amount of early parental language input is systematically related to the household socioeconomic status of a child. In their longitudinal study of children from diverse SES backgrounds, Hart and Risley (1995) found that children from the highest SES families heard over three times as many words per hour as children from the lowest SES families. Indeed, SES-related differences may impact differences in language processing via differences in linguistic exposure even in infancy (Fernald et al., 2012). Less explored is the relationship between early and ongoing differences in social and linguistic experience and outcomes past the school years, into early adulthood and mature language processing.

In adulthood, a great deal of evidence suggests that online language processing is anticipatory in nature, with listeners often predicting or pre-activating words before they are encountered (see DeLong, Troyer, & Kutas, 2014, for a review). Relatedly, when individuals encounter unexpected linguistic information, they must update their mental representations to accommodate the new information (e.g., Thornhill & Van Petten, 2012; DeLong, Quante, & Kutas, 2014; see Brouwer, Fitz, & Hoeks, 2012 and Van Petten & Luka, 2012, for reviews). However, the mechanisms by which linguistic information is anticipated, processed, and (possibly) amended remain unclear. Language is used productively and creatively, so the ability to predict multiple outcomes during language processing, or to shift expectations in the face of disconfirmed predictions, could be beneficial to the language comprehender (e.g., Boudewyn, Long, & Swaab, 2015). An open question involves whether (and under what circumstances) people concurrently pre-activate multiple possible lexical continuations during language processing, and whether this ability supports flexible interpretation of language when expectations are not met. Lifetime language experience may lead to individual differences in the activation of multiple and competing sentential outcomes. For example, individuals who have experienced richer and more varied language contexts, such as those more commonly experienced in higher

SES households, may similarly activate a richer and more varied set of predicted outcomes as a sentence unfolds. We explore this hypothesis in this study using an eye-tracked sentence comprehension task.

To motivate the current work, we first describe general relationships between SES and cognitive development. We next describe associations between SES and early differences in language experience, which relate to language processing differences in older children. We then present two experiments investigating SES-based individual differences in anticipatory language processing in young adults attending college at two large, geographically distinct universities in the United States.

1.1. SES and broad implications for development

Socioeconomic status is a construct defined by a number of factors related to income and environment, with higher SES generally indicating greater occupational, educational, and economic prestige (see Krieger, Williams, & Moss, 1997, for a discussion of how to define the construct of SES). Importantly, SES is connected to a range of physical, cognitive, and emotional factors that can influence development starting from gestation (Bradley & Corwyn, 2002; Stiles, 2008).

Individuals from lower SES backgrounds are more likely than peers from higher SES backgrounds to experience a number of physical, cognitive, and emotional challenges in their neighborhood and family environment throughout development. Lower SES households often have access to lower quality medical care, schools, and nutrition than higher SES households. They are also more likely to be exposed to physical toxins, violence, and chronic stress (Bradley & Corwyn, 2002; Brody et al., 1994; Evans, 2004) and less likely to experience cognitively stimulating environments during childhood (e.g., access to books, toys, etc.) which, in combination with other challenges, may negatively impact development (Bradley, Corwyn, Burchinal, McAdoo, & Coll, 2001; Farah et al., 2008).

Individuals from lower SES households are less likely than higher SES peers to achieve high academic and professional attainment in adulthood (e.g., Duncan, Yeung, Brooks-Gunn, & Smith, 1998). Socioeconomic status is also positively correlated with measures of cognitive development, including selective attention, short- and long-term memory, and, in particular, executive function and language skill (Hackman, Farah, & Meaney, 2010; Herrmann & Guadagno, 1997; Neville et al., 2013). These findings from diverse fields and on multiple health and cognitive outcomes indicate that socioeconomic disparities in childhood have wide-ranging impacts that extend into adulthood.

1.2. SES and language development

Just as SES is related to other cognitive skills, it is associated with nearly every aspect of language ability ranging from the capacity to recognize the sounds of language (i.e., phonological awareness) to understanding and producing cohesive narratives (see Hoff, 2013, and Pace, Luo, Hirsh-Pasek, & Golinkoff, 2017, for recent reviews). Notably, there is a strong correlation between vocabulary and SES: Children from lower SES households tend to have smaller productive and receptive vocabularies than their peers from higher SES households (Hoff, 2003; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Pan, Rowe, Singer, & Snow, 2005).

This association arises at least partially from dramatic differences in early language environments in higher versus lower SES households. The quantity and quality of speech to children vary tremendously as a function of SES (Hart & Risley, 1995; Hoff, 2003, 2006; Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Pan et al., 2005; Rowe, 2012; Weizman & Snow, 2001). For example, Hart and Risley's (1995) well-known study estimated that children living in poverty hear fewer spoken words (as many as 30 million fewer words between the ages of 12–36 months) than peers from higher SES backgrounds. However, other environmental factors, such as parents' knowledge of child development (Rowe, 2008) and sensitivity to children's verbal behavior (Baumwell, Tamis-LeMonda, & Bornstein, 1997), can also contribute to the impact of SES on language measures during development.

SES-related differences in language skills emerge in infancy (Halle et al., 2009), and these differences have important consequences for the development of speech processing skills. Fernald et al. (2012) assessed the vocabulary and lexical processing skills of children from diverse socioeconomic backgrounds between the ages of 18 and 24 months. Strikingly, they found that differences in both measures as a function of SES appeared even at 18 months. An additional study by Weisleder and Fernald (2013) revealed that processing differences were directly associated with variability in the quantity of parental speech in lower SES households.

In addition to the total number of words children hear (number of *tokens*), there is additional evidence that the number of different words (number of *types*) matters for children's early language development. Low-frequency words seem particularly important, and only children who hear a larger number of *types* will hear these words (Weizman & Snow, 2001). It is likely that the shape of the distribution of words (including the variability in *types*) that a child is likely to hear will also vary systematically with SES.

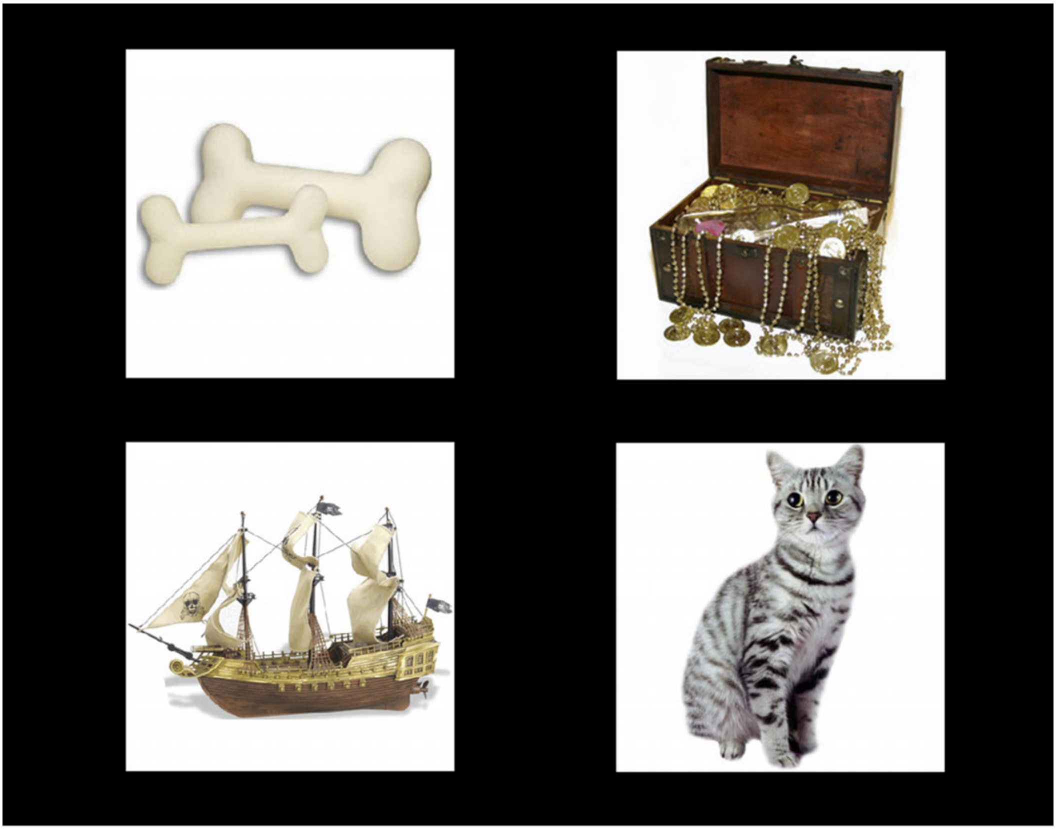
Relatedly, another mechanism by which SES may exert a particularly powerful influence on language development is exposure to print (e.g., Cunningham & Stanovich, 1990). Children from lower SES environments may have exposure to fewer books than their higher SES peers both in the home and at school (Bradley et al., 2001; Duke, 2000; Neuman & Celano, 2001). Moreover, Montag, Jones, and Smith (2015) found that language in picture books contains greater lexical diversity than language in typical parent–children conversations, coinciding with findings that diverse language input (as opposed to simply *more* language input) is associated with positive outcomes in language development (Hart & Risley, 1995; Huttenlocher et al., 2010; Weizman & Snow, 2001). These findings suggest that children from lower SES backgrounds may receive fewer words and less diverse linguistic input from both verbal and written language compared to peers from higher SES backgrounds.

The relationships between SES and early linguistic and literacy environments, early language skills, and subsequent linguistic and academic success support the notion that early differences in SES can have cascading consequences for language processing throughout early and later childhood. However, little is known regarding whether or how these early differences in language environment may lead to longer term differences in language processing skills. The answer to this question may have important theoretical and practical implications for how early environments shape long-term language learning and outcomes. We therefore explore how maternal SES relates to language processing in college-aged students.

1.3. The current study

We use the visual world paradigm (Huettig, Rommers, & Meyer, 2011; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) in our investigation, as it has been sensitive to individual differences in a variety of child, adolescent, and adult language processing tasks (e.g., Borovsky, Elman, & Fernald, 2012; Mishra, Singh, Pandey, & Huettig, 2012). In a typical visual world study, the location of participants' gaze to items in a visual scene is tracked while they listen to spoken language. Researchers can link outcomes from eye movements—which plausibly reflect some of the current contents of thinking—to different experimental conditions. A recent study of the visual world paradigm as a viable measure of individual differences in spoken word recognition found moderate-to-high test-retest reliability on several fixation measures (Farris-Trimble & McMurray, 2013). This paradigm is therefore well suited as a measure for assessing rapid language processing in adults as a function of SES.

In previous work using the visual world paradigm, Borovsky and colleagues measured real-time sentence comprehension in several populations, including young children, adolescents, and college students (Borovsky, Burns, Elman, & Evans, 2013; Borovsky et al., 2012). In each study, participants heard simple, SVO sentences, such as "*The pirate chases the ship*" that contained two semantically informative cues (an agent and an action) that coordinated with the sentence-final object. As the sentences were spoken, participants viewed a visual array containing four objects that varied in their relation to the agent and action of the sentence (see Fig. 1). The four objects were (a) a Target item (SHIP) that was related to the agent and action of the sentence and corresponded with the spoken sentential object; (b) an Agent-related object, which was related to the subject noun of the sentence, but not the action (e.g., a pirate-related image of TREASURE); (c) an Action-related item that was related to the spoken action verb, but not the agent (e.g., a chase-able item, like CAT); and (d) an object that was Unrelated to the sentence (e.g., BONES). Multiple populations (children, young adults, and adolescents) have previously demonstrated robust anticipatory fixations toward the Target item (SHIP) before it was spoken, indicating that participants rapidly integrated agent and action cues to generate a prediction for the sentence-final object, though the speed of prediction has varied with vocabulary skill in children and adults (Borovsky et al., 2012). Interestingly, participants also showed a lesser degree of looks toward relevant distractors as the sentence unfolded. As the verb (*chases*) was spoken, both children and adults also generated additional looks to the Action-related item (the chase-able CAT), compared to the Unrelated image in the display, indicating that they



Spoken sentence					**Target**	**Noun-Related**	**Verb-Related**	**Unrelated**
The	*pirate*	*hides*	*the*	*treasure.*	TREASURE	SHIP	BONES	CAT
The	*pirate*	*chases*	*the*	*ship.*	SHIP	TREASURE	CAT	BONES
The	*dog*	*hides*	*the*	*bones*	BONES	CAT	TREASURE	SHIP
The	*dog*	*chases*	*the*	*cat*	CAT	BONES	SHIP	TREASURE
Art1	Noun	Verb	Art2	Target				

Fig. 1. Sample images used during the experimental task. Figure reproduced with permission from Borovsky et al. (2012).

considered not only the most likely continuation (SHIP), but also an additional, plausible (though less likely) continuation (CAT).

We therefore had reason to suspect SES background might influence anticipatory language processing in two distinct, though not mutually exclusive, ways. (1) The quantity and quality of lifetime language experiences differ between higher and lower SES groups (Hart & Risley, 1995; Hoff, 2003, 2006). We suspected these differences might shift the degree to which listeners activate uncertain or unexpected outcomes during linguistic processing. We therefore expected that individuals from lower SES backgrounds might anticipate fewer alternate continuations during our language comprehension task.

(2) Given the results that (a) SES background influences speed of lexical processing in infancy, (b) SES background is positively correlated with vocabulary, and (c) vocabulary level influences speed of anticipatory language processing in both children and adults, we predicted that young adults from lower SES backgrounds might show relative slowing during our language comprehension task. We explore these two possibilities across two experiments by measuring the relationship among SES and language processing measures in college-aged adults attending public institutions in two geographic regions of the United States: southern California (Experiment 1) and northern Florida (Experiments 1–2). In Experiment 1, we compare performance as a function of SES on a sentence processing task (Borovsky et al., 2012) that has previously highlighted differences based on levels of vocabulary in both college-aged adults and in children. In Experiment 2, we use a variant of this task to further examine the relationship between SES and language comprehension in the face of unexpected content. We describe these tasks in greater detail below.

2. Experiment 1

2.1. Method

2.1.1. Participants

A total of 145 English-speaking college participants were recruited for this experiment across two large public universities at geographically distinct regions in the United States. This large sample size resulted from (a) a desire to extend recruitment to two separate universities and to compare SES distributions among the research pool in two different communities, and (b) a desire to have a sample size large enough at each university to ensure a sizable SES range. Of this sample, 50 native English-speaking college students (39 women; 11 men) between the ages of 18 and 26 (M = 20.6 years) participated at the University of California, San Diego (UCSD) for partial course credit. Participants were excluded from data analysis if they reported exposure to languages other than English during early childhood (13 participants) or any current or prior hearing or speech disorder (two participants). Thus, 35 participants from this university were included in the reported analyses. These participants all provided informed consent for the study, which was approved by the University of California, San Diego Institutional Review Board.

An additional 95 English-speaking college students (69 women; 23 men[1]) between the ages of 18 and 23 (M = 20.1 years) participated at the Florida State University (FSU) in return for course credit. Participants were excluded from data analysis for any of the following: reported exposure to languages other than English during early childhood (12 participants); any current or prior hearing or speech disorder (five participants); or incorrectly recorded or incomplete data (five participants). This left 73 participants from FSU whose data were analyzed, and a total of 108 participants in the combined sample. These participants all provided informed consent for the study, which was approved by the Florida State University Institutional Review Board.

2.1.2. Stimuli and design

The stimuli and task for this experiment were the same as those used previously by Borovsky et al. (2012, 2013). Linguistic materials consisted of eight sentence quartets which were created by crossing two agents and two actions to create four sentences as in (1). These sets were paired with four images related to the content of the sentences. For instance, the sample item in (1) was paired with images of a treasure chest, a pirate ship, a cat, and some bones (see Fig. 1).

(1)	*The pirate hides the treasure.*
	The pirate chases the ship.
	The dog hides the bones.
	The dog chases the cat.

On a single trial, participants saw all four images concurrently as they heard the sentence unfolding. Each of the images served a different purpose for each of the sentences in the quartet. For example, for the sentence *The pirate hides the treasure*, the Target image was the TREASURE, the Agent-Related distractor image was the SHIP (ships are related to pirates), the Action-Related distractor image was the BONE (bones are objects that are often hidden), and the Unrelated distractor image was the CAT. For the sentence, *The pirate chases the ship*, the Target image was the SHIP, the Agent-Related distractor image was the TREASURE, the Action-Related distractor image was the CAT, and the Unrelated distractor image was the BONE. In this way, each of the images appeared once in each condition and was able to serve as its own control, mitigating the possibility that differences among images would lead to systematic differences in eye movements.

The images were all 400 $\times$ 400 pixels and were photo-realistic examples of the Target items. A previous norming study conducted by Borovsky et al. (2012) indicated that young children (ages 3–4) were able to recognize and understand the stimuli. The auditory stimuli we used were recorded by the second author and were edited in Praat audio edition software (Boersma, 2001) to normalize the length of each word across sentences. In this way, the first article, agent noun, action verb, second article, and target noun each had a specific duration (see Borovsky et al., 2012, for more details on auditory stimuli creation).

Each participant heard a total of 16 of the entire set of 32 sentences, with two out of the total four sentences per set being heard by an individual participant. In this way, a single image array was seen twice by each participant. Versions of the stimuli were balanced across participants, and across versions, each object was presented an equal number of times in each quadrant of the screen. Likewise, the Target image appeared equally frequently in each quadrant within each version.

2.1.3. Experimental procedure

Participants were seated comfortably in front of a 17-inch LCD display. At the start of each session, the eye-tracker was calibrated for each participant using a black-and-white 20-point bull's-eye image. We used EyeLink Experiment Builder software (SR Research, Mississauga, Ontario, Canada) to present stimuli. Participants were told that they would be seeing images and hearing spoken sentences and instructed to click on the picture that "goes with the sentence." As in previous studies, we expected participants to click on the sentence-final noun, which was the Target in our design. Participants completed one practice trial before beginning the experiment.

Prior to each trial of the experiment, a fixation point appeared on the screen which was the same bull's-eye from the calibration routine. This fixation point also served as a drift check prior to recording for each trial. Before the sentence began, participants were able to freely view the four-image array on the screen for 2,000 ms. The images remained on the screen through the duration of the sentence and until the participant clicked on a picture. Halfway through the study, participants were offered a break. The eye-tracking portion of the experiment lasted approximately 10 min.

2.1.4. Eye-movement recording

We used an EyeLink 2000 remote eye-tracker with remote arm configuration (SR Research) at 500 Hz for the data collected at UCSD and an Eyelink 1,000 + remote eye-tracker with identical camera and data sampling configuration at FSU. We recorded fixations, saccades, and blinks for each trial beginning at the appearance of the image array until the participant clicked on a picture at the end of the trial. Here, we report analyses on the data binned into 50-ms intervals (done offline) as well as in longer time periods of interest.

2.1.5. Offline measurements. SES

Our measure of SES was derived from the Barratt Simplified Measure of Social Status (BSMSS; Barratt, 2006), which is an updated version of the classic four-factor Hollingshead measure of SES (Hollingshead, 1975). Prior to completing the eye-tracking task, participants completed a background questionnaire that included the BSMSS instrument. For each participant, we calculated a BSMSS composite score according to participant report of maternal and paternal education and occupation. Means for each subcomponent (maternal and paternal scores for education and occupation) are shown in Table 1. A Wilcoxon signed rank test indicated no sample (UCSD vs. FSU) differences for any of the measures, all *p*s > .30. Because previous research has indicated that maternal SES, rather than paternal SES or SES measures derived from both parents, can drive cognitive differences in children (e.g., Stevens, Lauinger, & Neville, 2009; Weizman & Snow, 2001), we expected that our maternal SES measures might better predict language processing differences into adulthood in our study. We therefore report results based on maternal SES.

The distribution of maternal SES scores for participants from each school (UCSD and FSU) is shown in Fig. 2. Maternal SES was not available for one participant, who was dropped from further analyses. The group means from each school were similar: $M = 47.06$ ($SD = 13.62$, Range = 12–66) for UCSD and $M = 47.04$ ($SD = 13.40$, Range = 12–66) for FSU. Furthermore, a Wilcoxon signed rank test indicated that these distributions did not differ from one another, $W = 1255$, $p = .97$, $r = .00$ (CI = [–5.00,

Table 1
Subcomponents of the socioeconomic status score for UCSD and FSU participants in Experiment 1

	UCSD		FSU	
Measure	Mean (*SD*)	Range	Mean (*SD*)	Range
Mother education	5.83 (1.12)	4–7	7.57 (1.04)	4–7
Mother occupation	5.92 (2.41)	0–9	5.96 (2.37)	0–9
Father education	5.94 (1.20)	4–7	5.82 (1.00)	4–7
Father occupation	5.86 (3.32)	0–9	6.68 (2.22)	0–9

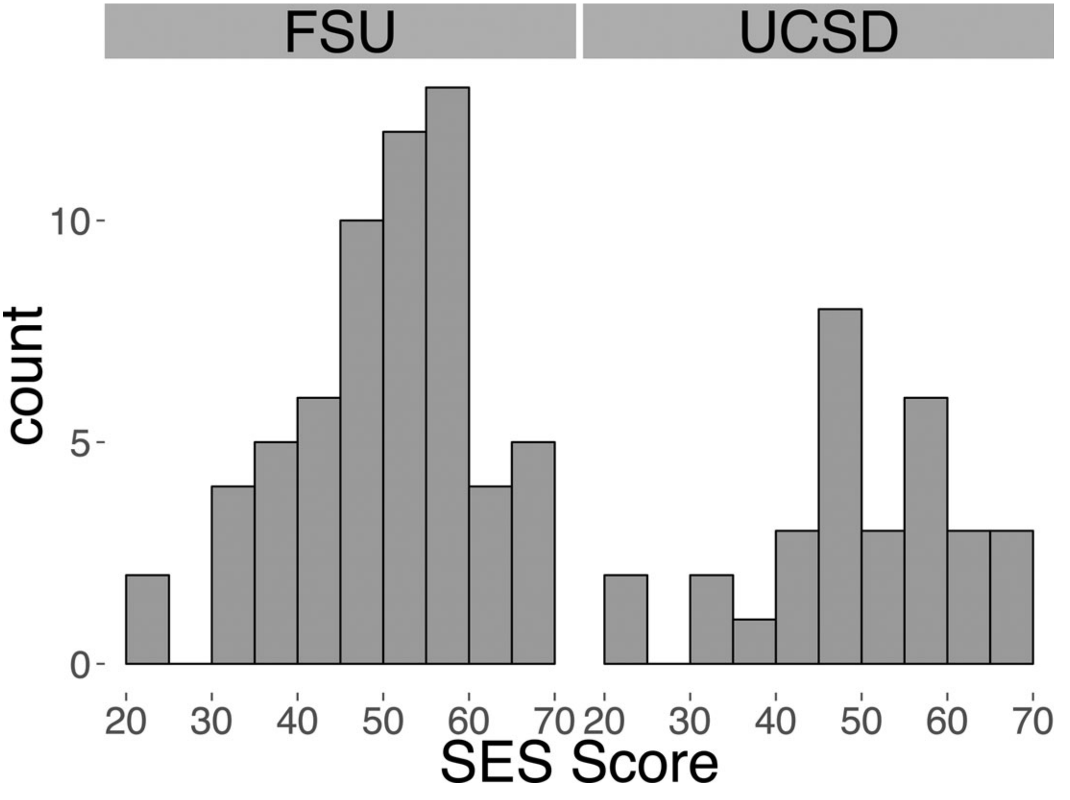


Fig. 2. Distribution of maternal socioeconomic status (SES) scores by dataset (FSU, UCSD) for Experiment 1 based on the Barratt (2006) measures.

5.00]). Therefore, we decided to pool the data from both groups. Subsequent analyses are performed on this pooled dataset. For group analyses based on SES, we split the data into two groups, higher and lower SES, using a median split. This led to the exclusion of eight participants who scored exactly the median, so the total number of participants included in these group analyses was $N = 99$, with 49 participants contributing to the higher SES group and 50 participants contributing to the lower SES group.

2.1.5.1. Vocabulary: After the eye-tracking task, participants completed a standardized test of receptive vocabulary, the Peabody Picture Vocabulary Test-Version 4 (PPVT-4; Dunn & Dunn, 2007). PPVT testing took approximately 15 min, and the entire experimental session was completed in less than 1 h.

Given prior results that vocabulary influences performance on the eye-tracking task employed here (Borovsky et al., 2012) and the known correlation between SES and vocabulary during development (e.g., Farkas & Beron, 2004; Hart & Risley, 1995), we wanted to calculate the degree to which our measurements of SES and PPVT were correlated with each other. We therefore measured the correlation between composite SES and PPVT. Due to experimenter error, PPVT data from five participants from the FSU sample were recorded incorrectly. These participants were excluded from all PPVT analyses but not from other analyses involving SES.

The correlation between maternal SES and PPVT was not significant, $r = .007$, $p = .94$. Due to the lack of a significant relationship between maternal SES and vocabulary measured by PPVT in our sample, we do not report any further analyses including PPVT as a factor. This lack of correlation also suggests that SES differences in our eye-tracking results were not, in fact, driven by differences in vocabulary skill between the two groups.

2.2. Results

2.2.1. Behavioral accuracy

To assess whether or not adults understood the experimental stimuli and attended to the task, we calculated the proportion of trials where participants selected the correct picture that matched the sentence-final theme out of all trials where a click was recorded (nine trials were excluded because participants were not looking to a valid interest area, and two trials were excluded because no response was recorded due to experimenter error). Accuracy on the task across all participants was very high ($M = 99.3\%$, $SD = 2.5\%$, with only 12 out of 1,726 recorded trials being incorrect). The maximum number of incorrect answers by any single participant was two out of 16 (three participants). On these trials, participants always selected the agent-related item rather than the theme, or final noun, of the sentence. We excluded these trials from analysis.

2.2.2. Eye-tracking data analysis

Our next analyses focus on fixations to the image array from the onset to offset of the spoken experimental sentences. Our first goal was to characterize the time course of fixations toward the target and distractor objects across the entire sentence before carrying out statistical comparisons of looks toward the target in time windows of interest.

2.2.2.1. Time course analysis: We initially illustrated the time course of fixations to the target and distractor objects from sentence onset to offset as a function of maternal SES. We therefore calculated the mean proportion of time spent fixating to the Target, the Agent-Related distractor, the Action-Related distractor, and the Unrelated distractor in

50 ms bins beginning at the onset of the sentence for higher SES and lower SES groups, displayed in Fig. 3.

As in previous work, we observed a shift in looks toward the Target and Agent-Related distractors during the first noun (the agent). We then observed a rapid shift in looks to the Target (compared to all distractors) following the onset of the verb. After this shift, the majority of looks remained on the Target for the duration of the sentence. In addition, there was an increase in looks to the Action-Related distractor shortly after the onset of the verb. All of these tendencies replicate patterns found in previous work using these materials (Borovsky et al., 2012, 2013).

Our first analytic goal was to explore differences in the timing of anticipatory fixations to the Target between SES groups. We initially focused our analysis on the time point at which looks toward the Target exceeded looks toward the Agent-Related distractor (henceforth referred to as the Target divergence point). Specifically, we identified the timing of Target divergence using a cluster-based permutation analysis. We then sought to determine whether there were SES-related differences in the timing of Target divergence. The procedure for this analysis is as follows.

First, we calculated log-gaze proportion ratios as our dependent measures of interest. We use this measure because the log-gaze proportion ratio transformation defines the bias of looking to the Target relative to a distractor and provides the benefit of allowing the

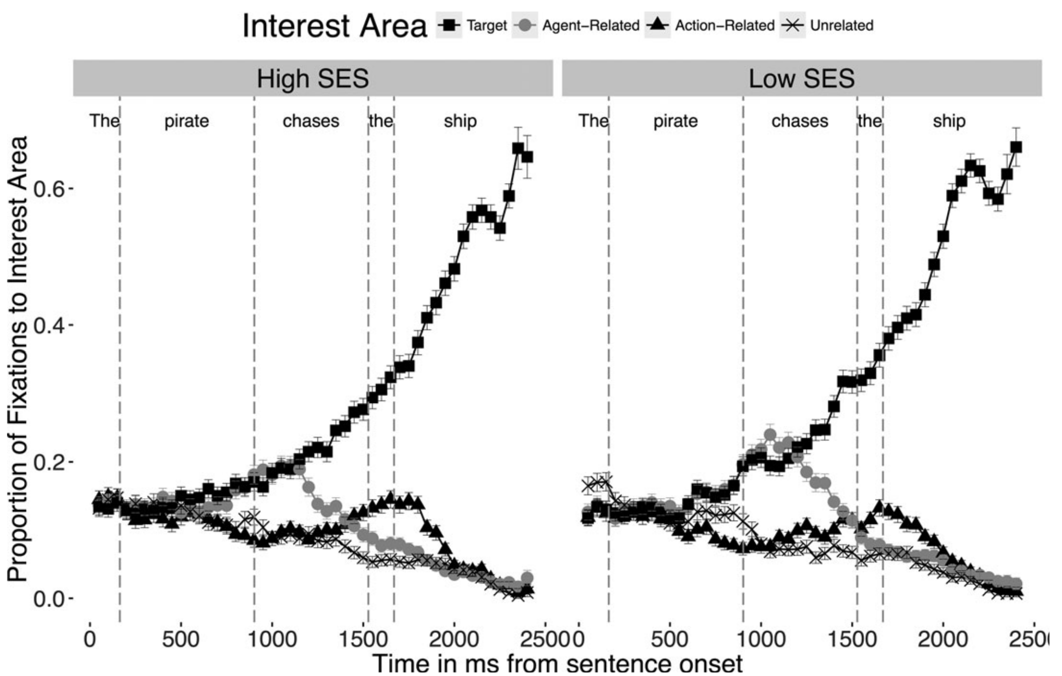


Fig. 3. Experiment 1 time course of fixations to the Target compared to distractor (Agent-, Action-, and Unrelated) interest areas over time in 50-ms bins (error bars represent standard error).

dependent variable to range in value between positive and negative infinity (for further explanation and similar approaches, see Arai, van Gompel, & Scheepers, 2007; Borovsky, Sweeney, Elman, & Fernald, 2014). Next, we carried out cluster-based permutation tests to compare fine-grained timing differences across multiple time points while maintaining power across many comparisons. This method identifies a "clustered" set of adjacent time points in which group differences exceed a threshold, and the cluster with the most extreme "mass" (cluster-level t score) is subjected to a permutation test (see Groppe, Urbach, & Kutas, 2011 for step-by-step explanation; see also Bullmore et al., 1999). We first compared the log-gaze proportion ratios of the higher SES group to the lower SES group. We next compared each group (higher and lower SES, respectively) against zero to determine the clusters at which each group looked more to the Target than to the Agent-Related competitor.

The cluster analysis did not reveal SES-related group differences at any time-point cluster in degree of looking to the Agent-related item versus the Target, cluster-based $t = 1.69$, $p = .65$. We also performed similar cluster-based permutation analyses on log-gaze ratios of each SES group (higher and lower SES) independently to determine the point at which the log-gaze ratio of Target to Agent-Related distractors exceeded zero. The higher SES group looked more to the Target than to the Agent-Related distractor starting at 1,150 ms post-sentence onset (or about 500 ms before the onset of the sentence-final theme; cluster-based $t = 374.36$, $p < .001$), and the lower SES group looked more to the Target than to the Agent-Related distractor by 1,200 ms post-sentence onset (or about 450 ms before the onset of the sentence-final theme; cluster-based $t = 393.27$, $p < .001$). We therefore found minimal evidence that SES affected the initial timing of anticipatory looks to the Target in our sample.

2.2.2.2. Effects of SES on the magnitude of fixations during pre-determined time periods: The prior analyses investigated whether there were group differences in *timing* of fixations toward target item by comparing fixations between groups in relatively short time bins. Next, we ask whether the *magnitude* of fixations to target and distractor items varies according to SES over two longer anticipatory time windows during (a) the sentential action and (b) the following article (see Kamide, Altmann, & Haywood, 2003, who use a similar approach in analyzing Experiments 2–3). These two time periods were selected as representative of the period of time when participants have initially encountered the necessary information to generate a robust prediction for the Target item but have not yet heard the sentential theme.

As our dependent measure for these analyses, we calculated the looking time toward the Target item relative to other distractors with log-gaze proportion ratios of looks to the Target versus Agent-Related distractor, Target versus Action-Related distractor, and Target versus Unrelated distractor. In this way, the relative looks to the Target versus each distractor could be combined into a single value for statistical analysis. For visualization, we present raw proportion of looks to the Target and each distractor by SES group in Fig. 4.

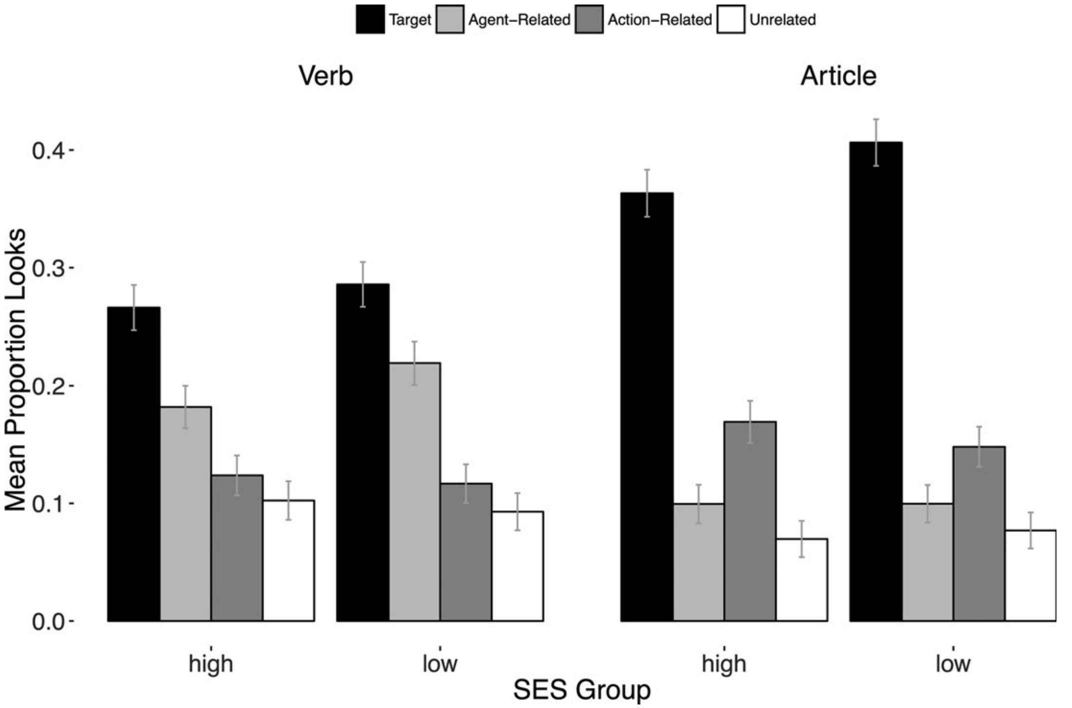


Fig. 4. In Experiment 1, mean log-gaze proportion comparing looks to the Target to looks to each of the competitors (Agent-, Action-, and Unrelated distractors) was computed for the verb and article time periods, respectively, for each socioeconomic status (SES) group. A larger number means participants were looking more toward the Target compared to the competitor. The most striking differences between high- and low-SES groups are observed for the Action-related competitors. Compared to the high-SES group, the low-SES group looked relatively less to the Action-related competitors (compared to the unrelated baseline). Error bars represent 95% confidence intervals over proportions.

In the following analyses, we computed correlations between raw maternal SES score and each of the dependent measures defined previously: log-gaze proportion ratios of looks to the Target versus Agent-Related distractor, Target versus Action-Related distractor, and Target versus Unrelated distractor.

During the action time period, there was no correlation between SES and looks to the Target versus Action-Related distractor, $r = -.11$, $p = .25$. During the article time period, however, there was a significant negative correlation between SES and looks to the Target versus Action-Related distractor, $r = -.20$, $p < .05$, indicating that individuals with higher SES scores were more likely to look toward the Action-Related item.

To illustrate the difference between looking times to the Action-Related versus Target distractor for the higher and lower SES groups, we re-plot raw looking times to these two interest areas over only the last three words, including both groups on the same plot (Fig. 5).

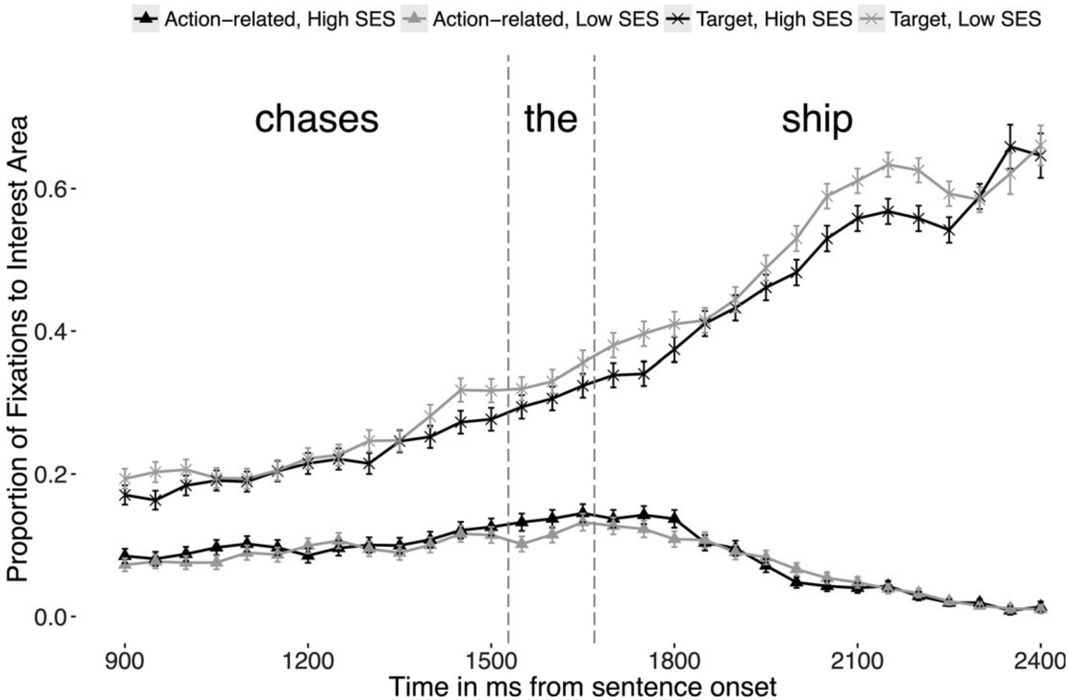


Fig. 5. Experiment 1 time course of fixations to the Target and the Action-related distractor by maternal socioeconomic status (SES) group in 50 ms time bin intervals (error bars represent standard error).

2.3. Discussion

In Experiment 1, we explored two hypotheses supported by prior findings in the literature: (a) that SES might be linked with speed of real-time language processing in adults, as previously reported in infancy and (b) that lexico-semantic dynamics/activation might vary as a function of SES. Our findings provide no support for the first hypothesis but support the hypothesis that lexico-semantic dynamics are influenced by differences in background linked with SES.

With respect to speed of anticipatory processing, we observed minimal SES differences in the point at which participants reliably looked to the target. Although infants show large SES-based differences in lexical processing, it appears that individuals from lower SES backgrounds “catch up” in terms of speed, at least in this relatively simple processing task making use of unchallenging stimuli originally designed to be understandable even by preschool children.

On the other hand, our findings lend greater support for a lexical activation account. We found that compared to peers from lower SES backgrounds, individuals from higher SES backgrounds appeared to show relatively greater activation for unexpected items that cohered with the local semantic content.

Experiment 1 therefore indicated there were SES-based differences in looks to a locally coherent, though globally less expected, item during incremental sentence processing. In particular, in simple SVO sentences of the form Agent-Action-Theme, we observed increased looks to an action-related item that was globally less expected shortly after participants began to hear the action (verb) of the sentence. A possible interpretation of these results is that background SES may be associated with the range of alternative lexical continuations that are considered, or possibly activated, simultaneously.

If individuals from lower SES backgrounds do indeed show relatively reduced activation for less likely sentence continuations, then we expect that background SES would have consequences on processing when such words are actually encountered in the course of sentence comprehension. We therefore predicted that individuals from lower SES backgrounds would be slower than peers from higher SES backgrounds to generate looks to a less expected, though locally coherent, item compared to one which was lexically unrelated to both the agent and to the action of the sentence. We test this prediction in Experiment 2.

3. Experiment 2

3.1. Method

3.1.1. Participants

Sixty English-speaking college students at Florida State University took part in the experiment for partial course credit. Of these, 52 participants (36 female, 16 male) between the ages of 18 and 23 (M = 20.5 years) were included in the data analysis. We excluded participants for not meeting age requirements (one participant), for reporting early childhood exposure to a second language (one participant), for reporting speech or hearing disorders (two participants), and due to technical errors (three participants). One additional participant was excluded for poor performance on the behavioral task (which was at ceiling for all other participants; see Results). All participants provided informed consent for the study, which was approved by the Florida State University Institutional Review Board.

3.1.2. Stimuli and design

The design of the experiment was similar to that of Experiment 1, except that participants heard sentences from two different experimental conditions: Action-Related and Unrelated. These sentences were created by taking the 32 sentences from Experiment 1 and replacing the final word with either the Action-Related word (corresponding to the Action-Related distractor picture from Experiment 1) or the Unrelated word (corresponding to the Unrelated distractor picture from Experiment 1). Participants therefore never heard the most expected ending type, only two unexpected (Action-Related or Unrelated) ending types, in the experimental sentences. In this way, the Target (i.e., the image corresponding to the final word of each sentence) differed between the two conditions. Each participant heard only 16 experimental sentences, so that no participant heard two sentences beginning with the same noun/verb pair. For example, a participant heard two of the eight sentences in the example below, one from the first set of four containing the first agent (*pirate*; i.e., one from sentences a–d) and a second from the second set of four containing the second agent (*dog*; i.e., one from sentences e–h).

(2)	a. *The pirate chases the cat.*	ACTION-RELATED TARGET
	b. *The pirate chases the bone.*	UNRELATED TARGET
	c. *The pirate hides the bone.*	ACTION-RELATED TARGET
	d. *The pirate hides the cat.*	UNRELATED TARGET
	e. *The dog chases the ship.*	ACTION-RELATED TARGET
	f. *The dog chases the treasure.*	UNRELATED TARGET
	g. *The dog hides the treasure.*	ACTION-RELATED TARGET
	h. *The dog hides the ship.*	UNRELATED TARGET

These items were interleaved with 32 filler items that contained sentences from an unrelated experiment. Importantly, these 32 fillers were sentences that depicted highly expected and plausible outcomes, thereby ensuring that the majority of sentences within the study (67%) depicted highly expected outcomes. As in Experiment 1, participants saw all four images concurrently as they heard the sentence unfolding. We were primarily interested in looks to the Target, still defined as the picture corresponding to the final word of the sentence spoken. For example, in the Action-Related sentence, *The pirate chases the cat*, the Target image was the CAT (see Fig. 1). As in Experiment 1, each image served as the Target and also as a non-target, serving as its own control.

Images were identical to those used in Experiment 1. The auditory stimuli we used were recorded by the second author and were edited as in Experiment 1 so that each word had a specific duration. However, the duration of each word in Experiment 2 was not identical to the duration of each word in Experiment 1 because different tokens were used to create the audio files.

3.1.3. Experimental procedure

The experimental procedure was identical to that of Experiment 1.

3.1.4. Eye-movement recording

We used an Eyelink 1,000+ remote eye-tracker (SR Research) at with a 500 Hz sampling rate, the same eye-tracker used in Experiment 1 at FSU. We used an identical procedure for data collection and binned data into 50-ms intervals for data analysis, along with using longer time periods of interest for analysis.

3.1.5. Offline measurements. SES

Our measure of SES was the same as in Experiment 1. Means for each subcomponent are shown in Table 2. The mean composite maternal SES score was 45.87 (SD = 14.18), a number similar to those obtained in Experiment 1. The range was 12–66. A Wilcoxon signed rank test indicated that the SES distributions from Experiment 1 and Experiment 2

Table 2
Subcomponents of the socioeconomic status score for participants in Experiment 2

Measure	Mean (*SD*)	Range
Mother education	5.67 (.98)	4–7
Mother occupation	5.77 (2.60)	0–9
Father education	5.41 (1.06)	4–7
Father occupation	5.87 (2.43)	0–9

did not differ from one another, $W = 2293$, $p = .588$, $r = .00$ (CI = [−5.00, 3.00]). For group analyses based on SES, we split the data into two groups, higher and lower SES, using a median split. This led to the exclusion of three participants who scored exactly the median, so the total number of participants included in these group analyses was $N = 49$, with 24 participants contributing to the higher SES group and 25 participants contributing to the lower SES group.

3.1.5.1. Vocabulary: As in Experiment 1, participants in Experiment 2 completed the PPVT-4. Again, we did not observe a significant correlation between SES and vocabulary scores on the PPVT in this sample, $r = .17$, $p = .23$. We take this lack of correlation to indicate that further SES-related differences are unlikely to be driven by differences in vocabulary ability across the sample. We therefore do not report any further analyses including PPVT as a factor.

3.2. Results

3.2.1. Behavioral accuracy

We calculated the proportion of trials where participants selected the correct target image at the end of each trial from the array of four images on the screen. Accuracy on the task was very high ($M = 98.35\%$, $SD = 8.7\%$), with all but one participant missing at most one trial. One participant selected the correct target on only 37.5% (6/16) of the trials and was excluded from further analyses due to poor accuracy. After data from this participant were removed, accuracy on the task was 99.52% ($SD = 1.68\%$), with a total of four errors out of 827 trials (one trial was discarded due to an error in recording). We excluded incorrect trials from further analysis.

3.2.2. Eye-tracking data analysis

Because the primary motivation of this study was to examine how listeners may recognize an unexpected sentence ending when it either did or did not cohere with the spoken verb (Action-Related vs. Unrelated conditions), our primary interest was in how participants viewed the Target (corresponding to the theme of the sentence) as a function of its relation to the action. Our primary goal was to determine whether there were differences in the timing of looks to the Target between conditions, Action-Related and Unrelated, as a function of SES. Finally, we performed statistical comparisons of looks to the Target in pre-determined time periods of interest: the verb, the second article, and the final noun (i.e., the theme of the sentence).

3.2.2.1. Time course analysis: Although the experimental sentences in Experiment 2 never ended with the most expected continuation (i.e., participants never heard sentences like "*The pirate chases the ship*"), the sentences did begin in the same way as in Experiment 1 and previous studies (Borovsky et al., 2012, 2013). As expected, we observed a shift in looks to the Expected and Agent-Related competitors during the time period when the first noun (e.g., "*The pirate*...") was spoken.

Because we observed group differences in Experiment 1 in how likely participants were to look to the Action-Related distractors following the onset of the spoken verb, our critical hypothesis was that maternal SES background would affect the speed with which participants looked to the Target in the Action-Related condition. Specifically, we predicted that individuals from higher SES backgrounds would be faster than those from lower SES backgrounds to recognize Action-Related Targets compared to Unrelated Targets. We therefore plotted looks to the Target for each condition (Action-Related and Unrelated) by maternal SES group in Fig. 6. Visual inspection reveals the predicted difference: for the higher SES group, there are large differences in proportion looks to the Target beginning during the verb, with a boost in proportion looks to the Action-Related Target earlier on. However, for the lower SES group, there is no such difference apparent during the verb period; in fact, there is very little difference between the two conditions

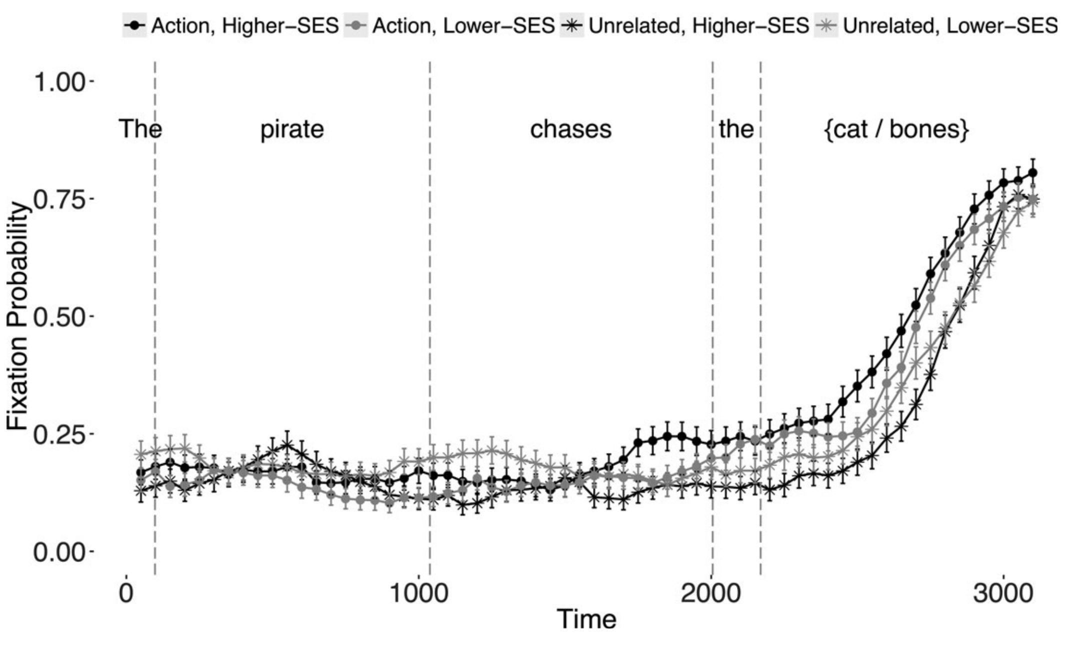


Fig. 6. Experiment 2 time course of fixations to the Target in the Action-Related and Unrelated condition by maternal socioeconomic status (SES) group (error bars represent standard error).

for the duration of the spoken sentence. We next describe statistical tests designed to analyze whether and when groups vary in their fixations to the Action-related Targets and Unrelated Targets.

As in Experiment 1, we used cluster-based permutation analyses over the entire period of the spoken sentence to determine the largest cluster of time points when differences between looks to the Action-Related Target were different from looks to the Unrelated Target. However, for the analysis comparing differences in looks to the Target based on condition and SES group, we were interested in how these two factors (condition, SES group) interacted. Because we found that the higher SES group in Experiment 1 did show greater looking than the lower SES group toward the Action-related distractor, we predicted that the higher SES group would look to the Target more readily (i.e., more looks, earlier) in the Action-Related compared to the Unrelated condition when compared to the lower SES group. We therefore subjected the data to a cluster-based permutation test using the interaction F-statistic computed by doing an analysis of variance (ANOVA). As before, we also used cluster-based permutation tests using a t-statistic to compare looks to each type of Target within each group to determine the time periods where looks differed for lower and higher SES groups, respectively.

We computed these analyses over log-odds ratios of each type of Target (Barr, 2008). Log-odds ratios are defined as the log of the ratio of the proportion of interest to 1 minus that proportion. Similar to the log-gaze ratios computed for our analyses in Experiment 1 (which are defined as the log of the ratio of the proportion of looks to one image to the proportion of looks to another image *on the same trial*), log-odds ratio transformations provide the benefit that the data are not bounded between 0 and 1, thereby allowing the dependent variable to range in value between positive and negative infinity. Because in this case, we were not interested in comparing looks to different images within the same trial, we were restricted to using log-odds ratios of a single proportion value as our dependent measure.

The cluster analysis of the interaction effect of SES group and condition (Action-Related vs. Unrelated) revealed no significant interactions. The largest cluster, which did not reach significance, was from 900 ms to 1,200 ms, a time period encompassing the end of the first noun (the agent) and the first part of the verb (cluster-based $F = 27.95$, $p = .16$). Although the interaction of group SES and condition did not come out in the predicted region (i.e., any region after the onset of the verb), we observed a large main effect in the cluster analyses for the higher SES group, but not the lower SES group. A large cluster was identified for the higher SES group from 1,600 ms to 2,950 ms (cluster-based $t = 71.03$, $p < .001$), driven by significantly greater looks toward the Action-Related Target compared to the Unrelated Target during this time window. This period corresponds to a period beginning mid-verb (approximately 600 ms post-verb-onset) and lasting until near the end of the final noun, or the theme (about 150 ms before the end of the entire sentence). For the lower SES group, however, the largest cluster occurred between 2,700 and 2,950 ms, and this cluster was not significant (cluster-based $t = 11.78$, $p = .13$). We interpret these results as suggestive evidence that differences in looks to the Action-Related Target versus Unrelated Target were apparent by the verb region for the higher SES group only. Although the predicted interaction was not observed using our cluster-based methods, this is perhaps unsurprising due to the statistical power required to achieve clustered interaction effects. Because finding an interaction within a cluster analysis requires continuous significant interaction effects over many small (50 ms) bins, a break in any single time bin will disrupt the size of the clustered interaction, thereby increasing the difficulty of detecting a significant cluster-based interaction. We next turn to further analyses computed over larger, pre-determined time periods of interest to further explore the relationship between SES and the looks to the Target in our two conditions.

3.2.2.2 Effects of SES on the magnitude of fixations during pre-determined time periods: We describe statistical comparisons of the magnitude of looks to the target in three pre-determined time periods. Because the experimental sentences in Experiment 2 were designed to end with unexpected endings of two types (Action-Related and Unexpected Targets), we set out to analyze three time periods: the verb, the second article, and the final noun (the theme). As in Experiment 1, we reasoned that differences in looks to the Target based on SES might begin to emerge as early as the verb region, but that we might also observe differences up to and including the final noun region, since the spoken noun in this region differed in each condition. As in the cluster analysis described above, we used log-odd ratios of looks to the Target as our dependent variable. Mean raw looking times were first computed for each time period of interest (verb, second article, second noun) for each of the four interest areas (Target and three distractors), and then log-odds ratios were computed for looks to the Target in each time period of interest. In particular, we were interested in looks to the Target (see Fig. 7). We predicted that, consistent with our cluster analyses, higher SES would be associated with looking more quickly to the Action-related Target than to the Unrelated Target, and individuals with lower SES scores would show relatively less facilitation for viewing the Action-related versus Unrelated target. Therefore, we expected that SES might be positively correlated with the difference between looks to the Action-Related versus Unrelated Targets during the time period when the verb was spoken and possibly in subsequent time periods.

We observed this correlation in the verb time window, $r = .35$, $p < .01$. There was no significant correlation between maternal SES and differences in looks to the Action-Related versus Unrelated Targets in either the second article or theme time periods (ps $> .10$).

3.3. Discussion

In Experiment 2, we predicted that SES background would influence looks to target items that were either related (Action-Related condition) or not (Unrelated condition) to the action verb of the sentence, though not globally the most expected condition of the sentence. In particular, we predicted that those with higher SES backgrounds would look more quickly to the target in the Action-Related Condition compared to the

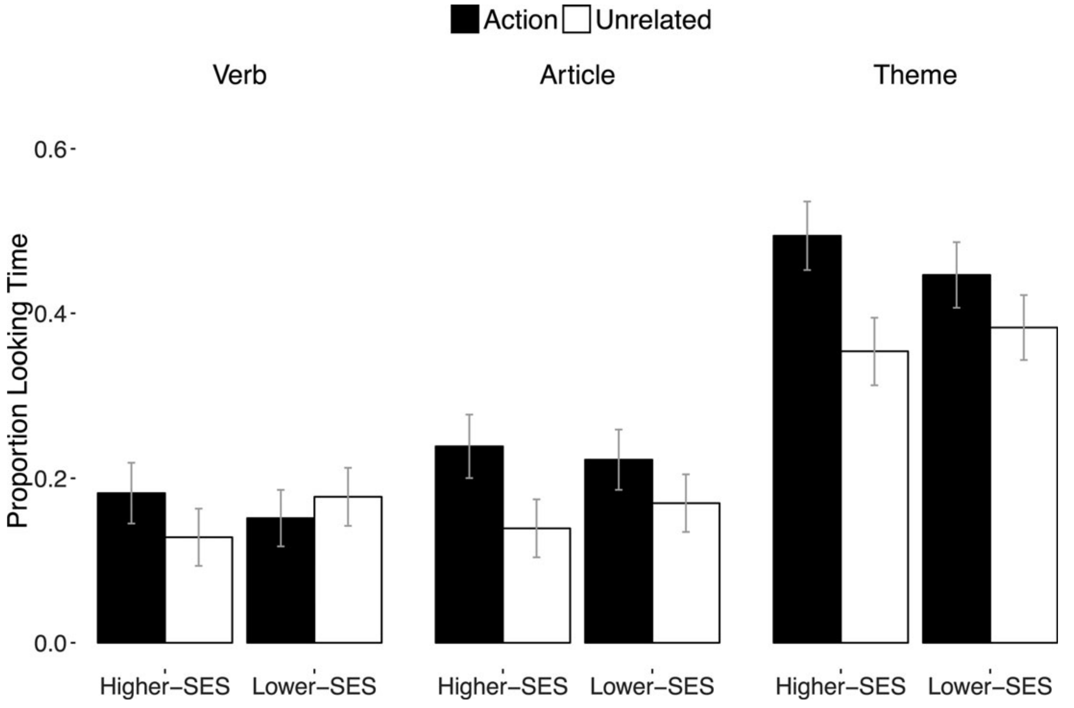


Fig. 7. Experiment 2 mean proportion looking time to the Target by maternal socioeconomic status (SES) group and condition for each period of interest (verb, second article, and theme). Error bars represent 95% confidence intervals over proportions.

Unrelated condition, and that this difference would not be present to the same extent in those from lower SES backgrounds. This pattern is precisely what we observed in Experiment 2. During the verb region, individuals from lower SES backgrounds did not show more looks to the Target when sentence-final words (the Target) were plausible, compared to implausible, arguments of the preceding verb. That is, individuals from lower SES backgrounds, on average, did not show increased looks to the Target for sentences like "*The pirate chases the cat*," where "*cat*" is a plausible argument for the action "*chase*," compared to sentences like "*The pirate chases the bones*," where "*bones*" is completely unrelated to the entire sentence. Individuals from the higher SES background, on the other hand, looked to the Target more quickly when the Target shared some relationship to the sentence (Action-Related condition) compared to the Unrelated condition.

Experiment 1 suggested the presence of differences in lexico-semantic activation during the processing of simple sentences with highly predictable endings. Our findings in Experiment 2 go further to suggest that differences in lexical activation can have processing consequences when sentence endings are not highly predictable. We explore this issue further in the General Discussion.

4. General discussion

We set out to explore whether childhood SES background may lead to differences in language processing into adulthood. To that end, college-aged adults listened to simple, SVO sentences during an eye-tracked sentence comprehension task across two experiments. We initially outlined two (non–mutually exclusive) hypotheses supported by previous findings in the literature: (a) that childhood SES may be linked with the *speed* of anticipatory processing in adulthood (as in infancy) and (b) that the dynamics of lexical/semantic activation in adulthood may vary according to childhood SES. Our findings lend little support to the first hypothesis and more strongly support the second.

In Experiment 1, undergraduates listened to sentences ending with predictable continuations while performing a simple task. We observed no evidence for SES-based differences in timing of anticipatory looks to a target image corresponding to the sentence-final word. However, we observed a systematic relationship between SES and looks to a local "competitor" during a time period when participants were able to anticipate the final word. Participants from higher SES backgrounds were more likely to look toward the Action-Related, or verb-related, competitor at this point compared to participants from lower SES backgrounds. This pattern led to a testable prediction regarding how these differences in lexical activation might influence language processing in unexpected contexts. Specifically, the findings from Experiment 1 suggested that there should be SES-related differences in processing of sentences with unexpected endings: sentences ending with a plausible Action-Related theme (e.g., *The pirate chases the cat*) should be more easily interpreted by individuals from higher (vs. lower) SES backgrounds.

We conducted a second experiment to investigate whether maternal SES was associated with processing unexpected words in sentence contexts. Participants listened to sentences with less predictable endings while performing the same task. Following our findings from Experiment 1, we predicted that participants from higher SES backgrounds (compared to lower SES peers) would interpret Action-Related sentence completions more rapidly compared to Unrelated completions. This is exactly the pattern we observed: During Action-Related trials, individuals from higher SES backgrounds looked more quickly to the Target than individuals from the lower SES backgrounds.

Our eye-movement data therefore suggest that childhood language background linked to maternal SES has implications for adult language processing. To the extent that looks to an image reflect mental states, including the activation of semantic content, we argue that SES may predict the amount of or type of lexico-semantic information that is available to language comprehenders in real time. Some listeners may enjoy rapid access to a larger range of related words (or semantic content) prior to encountering an upcoming word. In cases where listeners encounter highly expected words (as in Experiment 1), this difference may have little consequence for the speed or fluency of real-time comprehension. The alternatives which could have been (or were) considered do not necessarily have much to contribute to comprehension. If, however, the listener encounters an unexpected word in speech, then the number (and type) of alternatives available for consideration *would* be expected to have consequences. Entertaining a limited range of options might result in less flexibility, and when a word mismatches an expectation, this may result in slower recovery or interpretation of the unexpected, though plausible, outcome. Our data suggest that this may be the case for individuals from lower SES backgrounds.

A related possibility for the overall spike in looks to action-related competitors during Experiment 1, also noted in Borovsky et al. (2012), is that individuals may temporarily entertain locally coherent but globally unexpected linguistic information as a safeguard in case of encountering unexpected information in sentence comprehension. Indeed, several studies now suggest that adults temporarily activate locally coherent semantic and syntactic information in the course of normal language comprehension (Kukona, Fang, Aicher, Chen, & Magnuson, 2011; Tabor, Galantucci, & Richardson, 2004). This explanation is also consistent with connectionist models like TRACE (McClelland & Elman, 1986), which allows for temporary activation of items that are consistent with local context while inconsistent with prior (or subsequent) information. Under such an account, it is reasonable to suppose that individuals from lower (vs. higher) SES backgrounds might show relative difficulty in processing unexpected, unpredictable linguistic information if they are unlikely to pre-activate multiple possible outcomes.

A growing body of research has begun to explore the nature of lexico-semantic predictions during language comprehension. We know that people can pre-activate both word form and semantic information during sentence comprehension (e.g., DeLong, Urbach, & Kutas, 2005; Kamide et al., 2003). We suggest that SES-related variability in the quantity and quality of early language experience affects the number of lexical items (pre-)activated at any given point during language comprehension. Because individuals from lower SES backgrounds have likely been exposed to fewer words (both in terms of quantity and diversity) relative to peers from higher SES backgrounds in both spoken and written contexts (Hart & Risley, 1995), they may be less likely to pre-activate multiple lexical items for that context. This may relate to the probabilistic distribution of lexical items in a given context and not with total vocabulary per se. For instance, following a sentence beginning, *The boy is reading the*..., an individual experiencing a wealth of linguistic input might encounter words like *book*, *magazine*, *novel*, *poem*, *story*, and so on, whereas an individual experiencing a relatively lower amount/variety of linguistic input might only ever hear *book* in this context. It may therefore be more linguistically optimal for the former individual to "hedge their bets" and entertain a variety of outcomes, whereas an optimal strategy for the latter individual would be to stick with a single likely option (e.g., *book*).

As Weizman and Snow (2001) point out, as vocabulary grows, the proportion of lower frequency words to common words in the vocabulary will increase. In their study of a large corpus of mother-child (age 5) conversations, they found that the density of "sophisticated," or low-frequency, words in the input and their surrounding contexts accounted for 50% of the variance in second-grade vocabulary. Because less frequent words may have more specific meanings, it is reasonable to assume that they also carry more information, on average (see Piantadosi, Tily, & Gibson, 2011, for a discussion of frequency, informational content, and word length). If so, then less frequent words may occur in contexts that are less predictive. Children from lower SES backgrounds are more likely to hear more common words (Hart & Risley, 1995), perhaps in more limited (and, possibly, more predictive) contexts, than their higher SES peers. It may follow, then, that SES is related to the ability to pre-activate broader amounts of lexico-semantic information because some backgrounds do not afford the same linguistic opportunities. That is, if a child hears language containing highly stereotyped word use, then making multiple lexical predictions in a single instant might not be beneficial.

Our conjecture that adults from lower SES backgrounds (pre-)activate fewer lexical items in language comprehension leads to the prediction that these adults might encounter relative difficulty in situations where less likely or novel information occurs. For instance, interpretation of so-called garden-path sentences or other ambiguous content in language may be more difficult for individuals who are less likely to maintain multiple lexical (or syntactic) representations at once. In Experiment 2, we observed that the speed of looking to target pictures while listening to simple sentences with unexpected endings varied as a function of maternal SES. Similarly, interpretation of more complex language containing unexpected, or even unpredictable, content (i.e., containing words which are not predictable from context) may vary with maternal SES. We hope to investigate these hypotheses in future research.

While our findings suggest that childhood SES continues to exert an influence on adult language processing skills, we should note some important limitations regarding our sample. First, although we attempted to recruit a large, diverse sample, carrying out identical procedures at two geographically distinct public institutions across the United States (in the case of Experiment 1), our participants were nevertheless attending selective college institutions and gained entry partially by achieving requisite language scores on major standardized college entrance examinations. It is likely that recruiting a community sample of adults of similar ages would increase the range of socioeconomic backgrounds of our participants as well as variability in real-time language processing performance in our task. It is notable that, despite this restriction in SES variability in our sample, we still observed SES-related differences in language processing skills.

A second limitation is that we employed a simple task that was designed to be easily understood even by preschool-aged participants. It is possible that we would observe more robust differences in language processing with a more challenging task or more advanced vocabulary or grammatical structures. This is an opportunity for future study.

Finally, one additional limitation concerns the way we measured SES. We have used measures from the Barratt (2006) Simplified Measure of Social Status to estimate maternal SES. We have therefore estimated a static measure of maternal education and occupation. While parents' occupation and education could substantially change throughout an individual's lifetime, our measure likely reflects only the most recent occupational and educational status of an individual's parents. Therefore, we may be over-estimating childhood SES in our sample (perhaps more strongly at the higher end of the distribution). While this might merit some concern, our measure does seem to capture SES-related differences, and our scale was specifically adapted for SES-related research in college student populations (Barratt, 2006). In future work, more developmentally fine-grained measures of parental SES would be needed to specifically understand how changes in SES across development may influence language and cognitive development.

Despite these limitations, our findings highlight at least one way in which social inequities in childhood may impact adult language function. Our findings suggest that early SES-related differences in the language experiences of children have an impact in how adults navigate real-time language due to differences in the development of semantic expectations for speech. Given our observation that SES influences lexical activation patterns in college adults, we suspect that early SES may also influence adults in learning situations when they encounter novel or unexpected information, although further work is needed to understand precisely how this may occur. A greater implication of our findings is that early intervention in language skills is likely to have important positive implications even into adulthood for outcomes in the lives of children from lower SES backgrounds. Crucially, it is important to recognize the power of parental speech input in early childhood. A growing number of organizations, such as the 30 million word initiative in Chicago (tmw.org) and Providence Talks in Rhode Island, aim at empowering parents to boost their linguistic interactions with their children (see Pace et al., 2017, for a review of similar efforts). These parent-based language-enrichment programs are tremendously important and are likely to bolster the prospective academic, professional, and personal arenas of children raised in poverty. Our research suggests that these interventions may also lead to sustained benefits in language skills into adulthood.

Acknowledgments

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Note

1. An error in demographic data collection led to the failure to record the sex (and other background data) of two participants who were removed from subsequent analysis.

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