Cognition xxx (2016) xxx-xxx

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com

Original Articles

Exploring socioeconomic differences in syntactic development through the lens of real-time processing

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ARTICLE INFO

Article history:
Received 14 June 2016
Received in revised form 11 November 2016
Accepted 15 November 2016
Available online xxx

Keywords:
Socioeconomic status (SES)
Language processing
Syntactic development
Passive construction

ABSTRACT

Differences in caregiver input across socioeconomic status (SES) predict syntactic development, but the mechanisms are not well understood. Input effects may reflect the exposure needed to acquire syntactic representations during learning (e.g., does the child have the relevant structures for passive sentences?) or access this knowledge during communication (e.g., can she use the past participle to infer the meaning of passives?). Using an eye-tracking and act-out paradigm, the current study distinguishes these mechanisms by comparing the interpretation of actives and passives in 3- to 7-year-olds (n = 129) from varying SES backgrounds. During the presentation of spoken sentences, fixations revealed robust disambiguation of constructions by children from higher-SES backgrounds, but less sensitivity by lower-SES counterparts. After sentence presentation, decreased sensitivity generated interpretive challenges and average SES-related differences for passives requiring syntactic revision ("*The seal is quickly eat*en by *it*"). Critically, no differences were found when revision was not needed ("*It is quickly eat*en by *the seal*"). These results suggest that all children shared an ability to acquire passives, but SES-related differences in real-time processing can impact the accuracy of utterance interpretation.

1. Introduction

Striking differences in vocabulary development have been found in language acquisition across socioeconomic status (SES) (Arriaga, Fenson, Cronan, & Pethick, 1998; Hart & Risley, 1995; Hoff, 2003; Weisleder & Fernald, 2013). Notably, these effects are also present in syntactic development (Dollaghan et al., 1999; Hoff-Ginsberg, 1986; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Morisset, Barnard, Greenberg, & Booth, 1990; Vasilyeva, Waterfall, & Huttenlocher, 2008), an area that is traditionally argued to be resilient to variation in learning environments (Borer & Wexler, 1992; Newport, Gleitman, & Gleitman, 1977). Relative to lower-SES counterparts, children from higher-SES backgrounds, on average, produce more complex utterances (e.g., number of clauses, words per sentence) and diverse constructions (e.g., number of structural relationships) (Huttenlocher et al., 2010; Vasilyeva et al., 2008). These distinctions are mirrored in the communicative input to children from varying SES backgrounds (Cartmill et al., 2013; Hart & Risley, 1995; Hoff, 2003; Huttenlocher et al., 2007; Rowe, 2012). Compared to lower-SES counterparts, caregivers from higher-SES backgrounds, on average, produce more complex syntactic structures such as *wh*-questions, relative clauses, and raising adjectives (Huttenlocher et al., 2010).

Yet, far less is known about *why* relationships between language outcomes and caregiver input emerge in the first place or *what* aspects of development they reflect. One possibility is that SES-related differences reflect variation in learning. If specific language experiences (i.e., input quantity or quality) are required to acquire syntactic representations, then children may simply fail to learn constructions that are not frequently encountered. A second possibility is that SES-related effects are far more targeted. While children may acquire syntactic knowledge with minimal experience, input properties may facilitate access to this knowledge during real-time comprehension. If so, then SES-related differences may be isolated to situations where efficient access to previously acquired representations is necessary for interpreting an utterance. However, when utterance interpretation does not depend on efficient access to representations, then SES-related differences in comprehension may be minimal. To distinguish between effects of language experience during learning (e.g., does the child have syntactic representations?) versus communication (e.g., can she access them when she hears utterances?), the current study focuses on the comprehension of a low-frequency construction: the English *be*-passive. In the remainder of the Introduction, we will flesh out two perspectives on the role of caregiver input during syntactic development and examine their predictions for the scope of SES-related differences. We will then briefly consider why findings from prior research fail to distinguish between these hypotheses and discuss how the current study will tackle these limitations.

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http://dx.doi.org/10.1016/j.cognition.2016.11.004
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1.1. Two perspectives on input effects during language development

Accounts of SES-related effects on syntactic development often focus on how language experience impacts the acquisition of linguistic representations at the point of learning. As such, there is an underlying assumption that variable outcomes reflect differences in *forming* syntactic structures via frequency-driven associations between caregiver input and utterance meaning (Huttenlocher et al., 2002, 2007, 2010). These accounts share similarities to influential theories of acquisition including social-interactionist (Bruner, 1983; Snow, 1989) and usage-based approaches (Ambridge, Kidd, Rowland, & Theakston, 2015; Tomasello, 2000). They also provide an intuitive explanation for why SES-related effects are present in syntactic development. Since learning is predicated on adequate language experience, it is unsurprising that children from lower-SES backgrounds (who encounter less quantity and quality of input) lag behind their higher-SES counterparts (who encounter more), on average.

However, it is possible that the impacts of language experience may occur not at the point of *acquiring* representations, but when *accessing* this knowledge during communication. Recent research by Fernald and colleagues points to such a link in vocabulary development (Fernald, Marchman, & Weisleder, 2013; Hurtado, Marchman, & Fernald, 2008; Weisleder & Fernald, 2013). On average, 18-month-olds from lower SES families are slower to recognize highly familiar words in spoken sentences compared to their peers from higher SES families (Fernald et al., 2013). Individual variation in the speed of lexical processing predicts vocabulary size six months later, suggesting that real-time comprehension mediates relationships between language experience and vocabulary development. Nevertheless, the studies to date have focused on word recognition in simple and frequent syntactic contexts (e.g., "*Where's the dog?*"). Thus, it remains unknown how these effects influence development at later ages and in other language areas.

Interestingly, the role of input statistics is front and center in a parallel literature on adult syntactic processing. While theories differ in their goals and commitments, they share a basic assumption that the frequency of a structure directly affects its ease of retrieval from memory, e.g., limited repair parsing (Fodor & Inoue, 1994; Lewis, 1998), constraint-based models (MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994), surprisal theory (Levy, 2008), noisy-channel models (Gibson, Bergen, & Piantadosi, 2013; Levy, Bicknell, Slattery, & Rayner, 2009). The statistical properties of linguistic cues shed light on why sentences like (1a) are more difficult to comprehend compared to (1b), despite their equivalent meaning (Levy et al., 2009; Tabor, Galantucci, & Richardson, 2004). Since verbs like "*tossed*" are ambiguous between a relative-clause (i.e., the player who was tossed the frisbee → s/he received it) and active-clause interpretation (i.e., the player tossed the frisbee → s/he threw it), both syntactic structures are retrieved from memory when this cue is encountered in an utterance. In contrast, verbs like "*thrown*" are only consistent with a relative-clause interpretation, thus the likelihood that this structure is correctly accessed during comprehension is greater.

(1)	a. The coach smiled at the player tossed the frisbee by the opposing team.	
	b. The coach smiled at the player thrown the frisbee by the opposing team.	

Importantly, models of how input statistics shape comprehension within an individual may also explain how differences can arise between individuals. Even when syntactic knowledge is present across all children, variation in language experience may increase its ease of retrieval in some listeners compared to others. Efficient access may be particularly critical for interpreting garden-path sentences, where an initial syntactic analysis (e.g., hearing "*the player tossed the frisbee …,*" thinking that s/he threw it) needs to be revised after encountering later linguistic cues (e.g., hearing "… *by the opposing team,*" realizing that s/he received it). To do so, children must use cues to retrieve an alternative structure that fits with the updated linguistic context. This turns out to be quite difficult during development. Unlike adults, school-aged children (typically recruited from higher-SES families) often resist revision and adhere to misinterpretations across a variety of constructions (Choi & Trueswell, 2010; Huang, Zheng, Meng, & Snedeker, 2013; Hurewitz, Brown-Schmidt, Thorpe, Gleitman, & Trueswell, 2000; Omaki, Davidson White, Goro, Lidz, & Phillips, 2014; Trueswell, Sekerina, Hill, & Logrip, 1999; Weighall, 2008). Yet, little is known about how language experience impacts revision abilities during development and how these effects may contribute to SES-related differences in syntactic abilities.

1.2. Why comprehension of the passive construction may be informative

One challenge to addressing these questions is the widespread reliance on aggregated measures of language performance (e.g., mean length utterance, number of clauses, standardized assessments). These tools provide excellent summaries of the range of SES-related effects, but they can also obscure their underlying causes. In particular, these approaches fail to distinguish between whether SES-related differences in language comprehension reflect variation in the acquisition of syntactic representations (i.e., properties of caregiver input enables *some* but not all children to learn syntactic structures) versus real-time retrieval during communication (i.e., *all* children have knowledge of structures, but caregiver input enables some to access this more efficiently). Thus, to isolate the mechanisms underlying SES-related differences during syntactic development, it is necessary to adopt finer-grained measures of performance.

To this end, the current study focuses on children's comprehension of a well-studied test case: the active-passive alternation. Both constructions express the basic relationship of who did what to whom. In active sentences like (2a), the first noun phrase (NP1) maps onto the agent ("*the seal*" = PREDATOR) while the second noun phrase (NP2) maps onto the theme ("*the fish*" = PREY). In passive sentences like (2b), this order is reversed: NP1 is now the theme ("*the seal*" = PREY) while NP2 is the agent ("*the shark*" = PREDATOR). It is well documented that children readily comprehend actives, but generate many errors with passives (Gordon & Chafetz, 1990; Harris & Flora, 1982; Huang et al., 2013; Maratsos, Fox, Becker, & Chalkley, 1985; Messenger, Branigan, & McLean, 2012; Stromswold, Eisenband, Norland, & Ratzan, 2002; Sudhalter & Braine, 1985). This asymmetry has inspired several theories of syntactic development (see Huang et al., 2013 for a review). For our present purposes, we focus on two prominent accounts and consider their predictions for SES-related differences.

(2)	a. Active:	The seal is quickly eating the fish.
	b. Passive:	The seal is quickly eaten by the shark.

First, many have argued that children's difficulties with passives reflect their lack of experience with the construction (Brooks &

Tomasello, 1999; Demuth, 1989; Gordon & Chafetz, 1990; Harris & Flora, 1982). Passives are far less frequent than actives in the input. Stromswold et al. (2002) found that full passives accounted for less than 0.2% of adult utterances to children (see also calculations by Maratsos et al., 1985 and Gordon & Chafetz, 1990). Moreover, earlier proficiency is found in languages where passives are more frequent, e.g., Inuktitut (Allen & Crago, 1996), K'iche' Mayan (Pye & Poz, 1988), Sesotho (Demuth, 1989, 1990). Thus, it is plausible that SES-related effects on syntactic development reflect frequency-driven differences in acquisition that emerge within a single language. While we know of no study to date that has examined SES-related differences in input to passives specifically, related distinctions are well-documented with other complex structures (Huttenlocher et al., 2010). To the extent that low-frequency passives may be even less frequent for children from lower-SES backgrounds, it is possible that these children would be less likely to acquire this construction.

Nevertheless, errors with passives are also found among adults (Ferreira, 2003; Gibson et al., 2013; Huang et al., 2013; MacWhinney, Bates, & Kliegl, 1984). This suggests that their underlying cause may not reflect a lack of knowledge, but challenges in real-time comprehension instead (Bever, 1970; Huang et al., 2013; Turner & Rommetveit, 1967). Since passives cannot be distinguished from actives until after the onset of verb morphology (see (2)), children may initially misanalyze NP1s as agents and fail to revise this interpretation, even after encountering conflicting linguistic cues (e.g., past participle, *by*-phrase). Challenges with syntactic revision are well documented in convenience samples of children who tend to be from higher-SES families (Choi & Trueswell, 2010; Huang et al., 2013; Hurewitz et al., 2000; Omaki et al., 2014; Trueswell et al., 1999; Weighall, 2008). Moreover, SES differences in input are often found in structures that displace arguments from canonical positions (Huttenlocher et al., 2010). Thus, if efficient syntactic revision depends, in part, on encountering structures that require reanalysis, then SES-related effects may arise when comprehending passives, which often require revision.

1.3. The current study

The following experiment distinguishes these accounts by comparing the comprehension of active and passive sentences in 3- to 7-year-old children, from varying SES backgrounds. This age range lies at the intersection of three relevant literatures: (1) SES-related effects on syntactic development (Hoff-Ginsberg, 1986; Huttenlocher et al., 2002, 2007, 2010; Vasilyeva et al., 2008), (2) developmental difficulties with passives (Gordon & Chafetz, 1990; Huang et al., 2013; Maratsos et al., 1985; Messenger et al., 2012; Stromswold et al., 2002; Sudhalter & Braine, 1985), and (3) developmental difficulties with syntactic revision (Choi & Trueswell, 2010; Huang et al., 2013; Hurewitz et al., 2000; Omaki et al., 2014; Trueswell et al., 1999; Weighall, 2008). The current study recruits a language-processing task developed by Huang et al. (2013), which combines an eye-tracking paradigm (to assess on-line sensitivity to syntactic cues) with an act-out task (to assess the accuracy of utterance interpretation).

Children were presented with a series of active and passive sentences (Table 1), paired with three thematically related objects: Expressed item (SEAL), likely agent (SHARK), and likely theme (FISH). Following verb morphology (e.g., "*eating*" vs. "*eaten*"), preferences for the likely agent or theme provide an implicit measure of children's role assignment. In the Strong bias condition, definite NP1s are agents in actives (e.g., "*the seal*"), thus pronoun NP2s are likely themes (e.g., "*it*" = FISH). Conversely, when definite NP1s are themes in passives, pronoun NP2s are likely agents (e.g., "*it*" = SHARK). In Mandarin versions of these sentences (Huang et al., 2013), 5-year-olds (recruited from higher-SES backgrounds) are less accurate with passives compared to actives (52% vs. 74%). This pattern is consistent with a frequency account, which argues that children lack structures for low-frequency constructions. It is also consistent with a processing account, which argues that inefficient retrieval of low-frequency structures hinders revision of an agent-first bias. Both accounts predict that these challenges may be magnified in children from lower-SES backgrounds, who may have even less experience with passives.

Table 1
Sample sentences in the four critical conditions of the language-processing task. Each sentence was paired with a three-object set featuring the expressed item (SEAL), a likely agent (SHARK), and a likely theme (FISH). Targets referred to the correct identity of the pronoun. Competitors referred to the incorrect identity of the pronoun.

NP1 status	Construction	Sentence	Target	Competitor
Strong bias	Active	The seal is quickly eating it	Likely theme	Likely agent
Strong bias	Passive	The seal is quickly eaten by it	Likely agent	Likely theme
Weak bias	Active	It is quickly eating the seal	Likely agent	Likely theme
Weak bias	Passive	It is quickly eaten by the seal	Likely theme	Likely agent

Importantly, prior research suggests that properties of NP1 can modulate comprehension of passive cues (Huang et al., 2013). In the Weak bias condition, pronoun NP1s are likely agents in actives (e.g., "*it*" = SHARK) and likely themes in passives (e.g., "*it*" = FISH). Unlike definite NP1s (e.g., "*the seal*"), pronoun NP1s generate a weak agent-first bias.[1] Importantly, this delays role assignment until after the onset of the passive cue and NP2 (e.g., "*... (eat)en by the seal*"), and allows children to infer that NP1 is a theme, without needing to revise a misinterpretation. In this context, Mandarin-speaking 5-year-olds (recruited from higher-SES backgrounds) are as accurate with passives compared to actives (58% vs. 59%). Critically, if frequency differences between passives and actives do not impact the accuracy of interpreting sentences when syntactic revision is unnecessary, then a processing account predicts that SES-related differences should be minimal in the Weak bias condition. In contrast, if comprehension challenges with passives reflect a failure to acquire syntactic structures in the first place, then a frequency account predicts that SES-related effects will consistently emerge in both Strong and Weak bias conditions.

In addition to the language-processing task, we also assessed children's receptive vocabulary size. This measure served two purposes. First, since we did not directly quantify caregiver input, we wanted to verify that SES-related differences in language abilities were present in our sample. Input-related effects are well-established in vocabulary development (Arriaga et al., 1998; Hart & Risley, 1995; Hoff, 2003; Weisleder & Fernald, 2013), thus we used this as a proxy for variation in children's language experience (for similar approaches, see also Borovsky, Elman, & Fernald, 2012; Fernald, Zangl, Portillo, & Marchman, 2008; Mani & Huettig, 2012). Second, we examined

[1] Recent work suggests that this effect is driven by the discourse status of NP1 and not general properties of the expressions, e.g., frequency, semantic sparseness (Huang, Abadie, Arnold, & Hollister, 2016). When children interpret pronoun NP1s as referring to new entities, they become more likely to recruit an agent-first bias and generate passive errors. Similarly, when definite NP1s are contrasted with novel entities (e.g., "*the blicket*"), children consider them to be given entities and are less likely to apply an agent-first bias and produce passive errors.

whether syntactic processing can shed light on systematic relationships between SES background and vocabulary size. Admittedly, a cross-sectional design is not ideal for isolating questions of causality. It could be that syntactic processing facilitates vocabulary growth, or input-related factors promote both areas independently. Nevertheless, in the area of word recognition, the processing of spoken utterances is linked to vocabulary size in concurrent (Borovsky et al., 2012; Fernald et al., 2008; Mani & Huettig, 2012) and longitudinal measures (Fernald, Perfors, & Marchman, 2006; Marchman & Fernald, 2008; Weisleder & Fernald, 2013). This suggests that cross-sectional effects can provide hints to the range of relationships that may exist throughout development.

2. Methods

2.1. Participants

One hundred and thirty-one English-speaking children participated in this study. We excluded data from two participants due to absence during the second testing session (n = 1) and experimenter error during data collection (n = 1). This resulted in a final sample of 129 children (61 females, 68 males) with a mean age of 4;11 (SD = 0;9, range = 3;6–7;2). Children were recruited from local Head Start centers and private schools within the same geographical region. School status served as the initial basis for categorizing children's SES background (65 lower SES, 64 higher SES). For 85% of the sample, detailed measures were also obtained through a questionnaire of parental education and annual family income, which were transformed from categorical variables into years of education and income in US dollars. When two parents had different levels of education or income, the higher of the two was selected. Among the sample, parents averaged 14.9 years of education (SD = 2.6 years; Range = 8–18 years) and averaged an income of $51,882 (SD = $35,378; Range = less than $15,000 to greater than $90,000). Fig. 1 illustrates the distribution of children's ages across categories of family income.

Prior research indicated that children had substantial difficulties when the NP1 status of sentences varied across trials (Huang et al., 2013), thus we manipulated this factor between subjects. Sixty-three children were randomly assigned to the Strong bias condition and 66 to the Weak bias condition. Follow-up analyses confirmed that the two groups did not differ in age, gender, school status, parental education, family income, or vocabulary size (all p's > 0.30). This ensured that variation in performance across NP1 status would not be caused by baseline differences in the general demographics of these two groups.

2.2. Procedure

For each participant, measures of language performance were obtained over two testing sessions. The language-processing task was administered during the first session, which lasted about 20–30 min. Children sat in front of an inclined podium divided into four quadrants, each containing a shelf where an object could be placed. On each trial, the experimenter labeled the objects in each set individually as they were placed on the shelf in a pre-specified order. This was followed by a pre-recorded sentence describing an event. Children were then encouraged to pick up the objects and use them to act-out what was said. Once the participant did this, the trial ended and the objects were returned to their pre-specified locations on the shelf. This was followed by a second pre-recorded sentence describing another event involving the same objects. Once children performed this action, the objects were removed from the display, and the next trial began with a new set of objects. A camera at the center of the display was focused on children's face and recorded the direction of their gaze while they were performing the task. A second camera recorded both their actions and the location of the items in the display.

During the second session, receptive vocabulary was measured using the Peabody Picture Vocabulary Test-IV (PPVT; Dunn & Dunn, 2007). This lasted about 20 min. Testing items were divided into sets with 12 items each. For each item, children saw an array of four pictures and were asked to point to the one requested by the experimenter. They began with the set corresponding to their chronological age and stopped when they answered eight items in a set incorrectly. Since all our analyses statistically controlled for effects of age (see Section 3), we measured vocabulary size using raw PPVT scores.

2.3. Materials

Critical trial types for the language-processing task represented the cells of a 2 × 2 design. The first factor, construction type, contrasted active versus passive sentences. This was varied within subjects. The second factor, NP1 status, contrasted a strong agent-first bias for definite NPs (e.g., "*the seal*") versus a weak agent-first bias for pronouns ("*it*"). This was varied between subjects. Visual displays featured three-object sets that paired the expressed item (e.g., SEAL) with a likely agent (e.g., something that can plausibly act on the expressed item, like a SHARK) and a likely theme (e.g., something that the expressed item can plausibly act on, like a FISH). The size of the items was controlled to ensure the plausibility of the relationship. Likely agents were always larger than expressed items, which in turn were larger than likely themes. Predicted relationships across these items were independently confirmed through separate norming data (see Huang et al., 2013 for more details). Across trials, object types appeared in each location 33% of the time to ensure that roles could not be predicted based on the display arrangement.

For each object set, we constructed critical sentences like those in Table 1. All sentences mentioned a definite NP and a pronoun but varied in the order in which they occurred. Verb morphology distinguished between actives (i.e. present progressive) and passives (i.e., past participle). A *be*-auxiliary and adverb (e.g., "*is quickly*") were embedded between NP1 and the verb to create a period of ambiguity when role assignments could not be informed by the event.[2] Sentences were pre-recorded by a female actor who spoke in slow and consistent manner. Four versions of each item were used to create four presentation lists, such that each list contained six items in each condition and each item appeared just once in every list (see Appendix A for a full list of items). Twelve critical trials were pseudo-randomly presented with 32 additional filler trials that diverted attention away from the manipulated variables. To avoid systematically biasing the interpretation of NP1 as the agent or theme, filler sentences recruited symmetric predicates (e.g., "*dance*," "*fight*"), experience and stimulus verbs (e.g., "*like*," "*scare*"), and

[2] It is well-documented that *get*-passives are more frequent than *be*-passives among adults from lower-SES backgrounds (Sneller & Fisher, 2015; Weiner & Labov, 1983). While future work will investigate these differences, additional factors led us to first focus on *be*-passives. First, *get*-passives are more semantically restrictive (McEnery & Xiao, 2005), thus they were not felicitous over a wide range of stimuli items. Second, *get*-passives are less likely to occur with adverbial modifiers (Carter & McCarthy, 1999), which were included in the current study. Finally, SES-related differences in the frequency of *be*-passives are consistent with the linking assumptions behind predictions by the frequency and processing accounts.

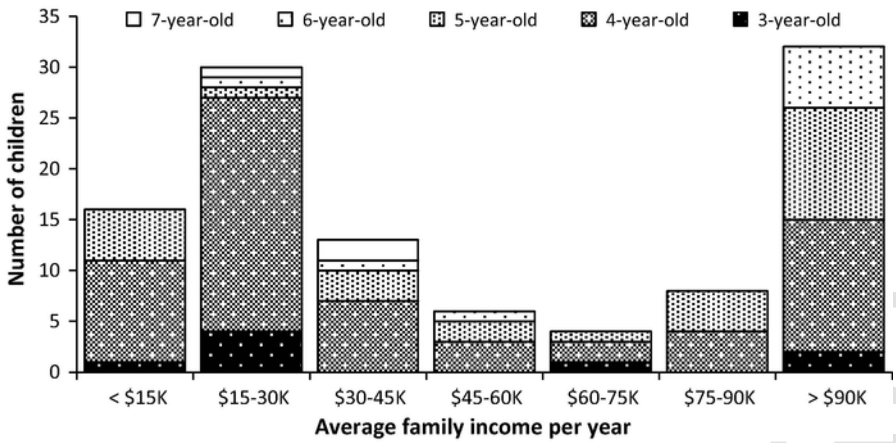

Fig. 1. A histogram of the average annual family income (in thousands of dollars) and age (in years) from 106 participants in the current study. This does not include information for 20 participants for whom a self-report survey was not returned.

agent/theme intransitives (e.g., "*sing*," "*break*") (see Huang et al., 2013 for more details).

2.4. Coding

Approximately 1.3% of trials was excluded from subsequent analyses because of experimenter error. Data from all other trials were coded in the following manner.

2.4.1. Fixations

Trained research assistants coded eye movements using the frame-by-frame annotation software, Vcode (Hagedorn, Hailpern, & Karahalios, 2008). Trials began at the onset of the instruction and ended with the onset of the corresponding action. Research assistants were always blind to object locations and trial conditions, and coded changes in gaze direction as looks towards one of the quadrants, at the center, or missing due to looks away from the display or blinking. Missing frames accounted for 10.9% of coded frames. Remaining looks were then recoded based on their relation to the trial condition (see Table 1). "*Target fixations*" were defined as looks to pronoun referents that were consistent with correct role assignment. For Strong bias/Passive and Weak bias/Active trials, this was the likely agent. For Strong bias/Active and Weak bias/Passive trials, this was the likely theme. "*Competitor fixations*" were defined as looks to pronoun referents that were consistent with incorrect role assignment. For Strong bias/Passive and Weak bias/Active trials, this was the likely theme. For Strong bias/Active and Weak bias/Passive trials, this was the likely agent. Twenty-five percent of trials were checked by a second coder who confirmed the direction of fixation for 92.1% of coded frames. Disagreements between the two coders were resolved by a third coder.

2.4.2. Actions

Research assistants also coded videotapes of actions and categorized responses based on the trial condition. "*Correct actions*" were defined as those that depicted correct role assignments between the expressed item and Target. For Strong bias/Passive and Weak bias/Active conditions, this referred to actions where likely agents did something to expressed items (e.g., making the SHARK eat the SEAL). For Strong bias/Active and Weak bias/Passive conditions, this referred to actions where expressed items did something to likely themes (e.g., making the SEAL eat the FISH). "*Reverse actions*" were defined as those that depicted incorrect role assignments between the expressed item and Competitor. For Strong bias/Passive and Weak bias/Active conditions, this referred to actions where expressed items did something to likely themes. For Strong bias/Active and Weak bias/Passive conditions, this referred to actions where likely agents did something to expressed items. "*Ambiguous actions*" were defined as incorrect actions where the expressed item was selected with no additional object, all three objects were selected, or no object was selected at all.

3. Results

Since our procedures did not include direct measures of caregiver input, it was important to first determine whether SES-related differences in language abilities were present in our current sample. Consistent with this assumption, Fig. 2 illustrates that children's vocabulary size correlated with family income ($r(101) = 0.49$, $p < 0.001$), parental education ($r(101) = 0.45$, $p < 0.001$), and school status ($r(127) = 0.46$, $p < 0.001$), while controlling for age. Given these robust relationships with a global measure of language ability, we isolated finer-grained effects in the following way. First, we examined fixations during sentences to assess on-line sensitivity to the syntactic cues that distinguish actives and passives. Second, we examined actions following the sentence to assess likelihood of revising initial syntactic interpretation. Third, we returned back to the presence of SES-related effects of vocabulary development in this sample and examined possible relationships between vocabulary size and syntactic-revision abilities.

Throughout our analyses, family income was used as a continuous measure of SES. This variable was highly correlated with parental education ($r(103) = 0.79$, $p < 0.001$) and school status ($r(106) = 0.91$, $p < 0.001$). Overall effects remained the same regardless of which measure was used, but they were most robust with family income as the predictor. Also, for ease of illustrating patterns in Figs. 3–6, we created SES groups based on a median split of family income (less or greater than $30,000) when these data were available and school status when they were not. Unless otherwise noted, dependent measures were analyzed using logistic mixed-effects models, including subjects and items as random-effects variables (intercepts only). Initial models split the data by NP1 status, and analyzed family income and construction type as fixed-effects variables. Follow-up analyses split by construction type and assessed effects of family income and NP1 status. Age (in months) was included as an additional predictor, but gender was omitted since it never improved model fit (all p's > 0.30).

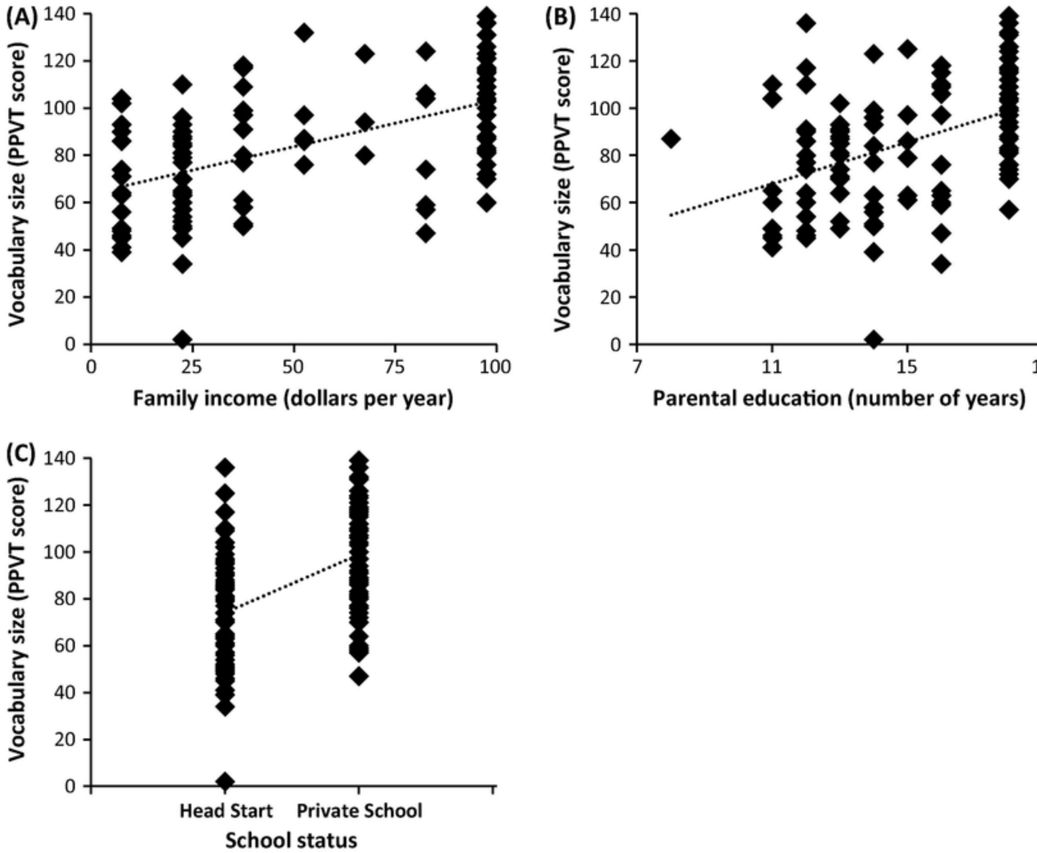

Fig. 2. Scatterplots illustrating relationships between vocabulary size (raw PPVT score) and (A) family income (dollars per year), (B) parental education (number of years), (C) school status (head start or private school).

Analyses were conducted using the lme4 software package in R (Bates, Maechler, Bolker, & Walker, 2013).

3.1. Fixation analyses

To assess on-line sensitivity, we time-locked fixations to when pronoun referents could be identified via linguistic cues in the speech stream. This corresponded to the onset of the verb morphology in the Strong bias condition (e.g., "*eating*" vs. "*eaten*") and the onset of NP2 in the Weak bias condition (e.g., "*seal*"). Regions of analyses continued until 500 ms after sentence offset, generating an average window of 1023 ms in the Strong bias condition and 1122 ms in the Weak bias condition. Also, preliminary analyses revealed that latency to look at the expressed item (e.g., SEAL) following the onset of the definite NP (e.g., "*seal*") was approximately 330 ms among a group of 40 adults but delayed until 530 ms in the current sample of children. We reasoned that any delays in restricting reference for definite NP would have cascading effects on role assignment and postpone looks to likely agents and likely themes (see Huang et al., 2013 for a similar approach). To account for this developmental difference, regions of analyses were shifted by 400 ms after the onset of the input in the speech stream (i.e., time between adults and children plus the standard 200 ms estimate of how long it takes adults to generate a saccadic eye-movement – see Matin, Shao, & Boff, 1993).

Figs. 3 and 4 illustrate that children often looked to the expressed item. This accounted for 44.4% of sampled fixations. To compare across conditions, we converted average, continuous fixations during the critical region of each trial into a binary variable (Jaeger, 2008). This binary variable accounts for the saccadic nature of eye-movements and best captured the underlying distribution of our data. While eye gaze was sampled every 33 ms, children typically made only one or two saccades in a single second. Consequently, any measure of fixation proportion within that window is essentially binary for each trial. If average fixations during this region were greater than 0.50, then values were coded as 1. If they were less than 0.50, then values were coded as 0. Approximately 4.5% of trials were excluded because of no looks to the expressed item or no preference in either direction (i.e., average fixations of exactly 0.50). Analyses revealed no effects of age, income, or construction type on fixations to the expressed item in Strong and Weak bias conditions (all z's < 1.00, all *p*'*s* > 0.15).

Importantly, Figs. 3 and 4 also illustrate that Target and Competitor fixations varied by condition. After the onset of verb morphology in the Strong bias condition (panels A and B), there was a preference for likely theme in active trials and likely agent in passive trials. This pattern appropriately switched after the onset of NP2 in the Weak bias condition (panels C and D). To compare linguistic and SES effects, we calculated preference scores for each trial. For passives, we subtracted Target minus Competitor looks, such that more *positive* values indicated greater sensitivity to passive cues. For actives, we subtracted Competitor minus Target looks, such that more *negative* values indicated greater sensitivity to active cues. We again converted average preference scores into a binary variable. If scores were greater than 0, values were coded as 1. If scores were less than 0, values were coded as 0. Approximately 15.7% of trials were excluded because of no Target or Competitor looks or equal looks to both ob-

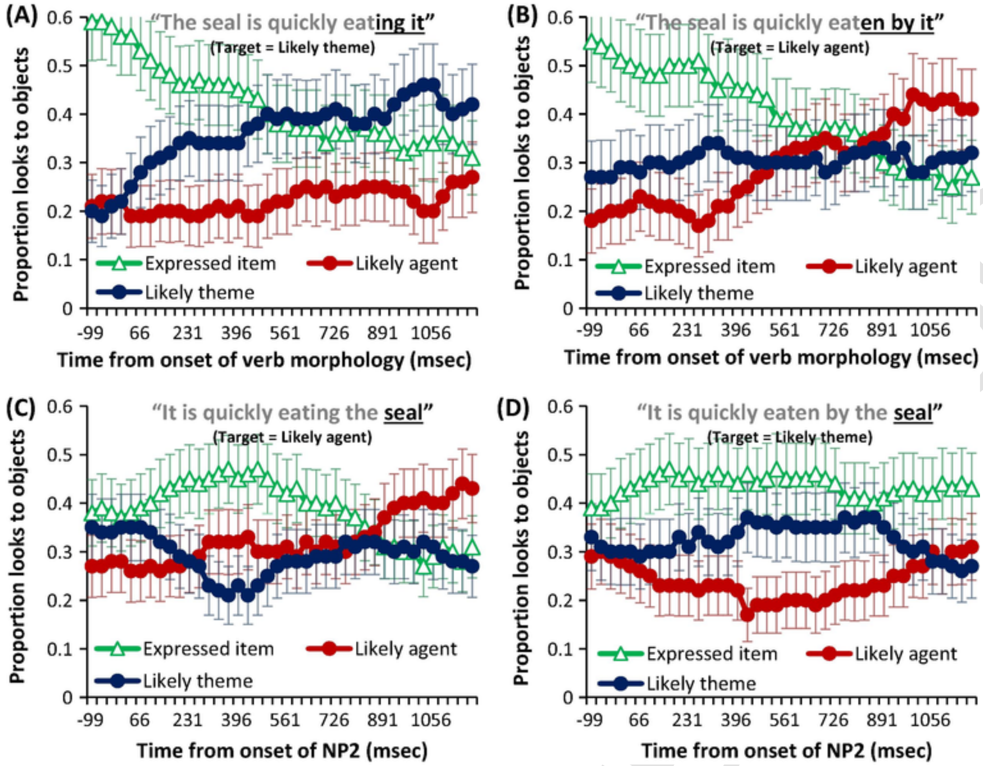

Fig. 3. Among children from higher-SES backgrounds, fixations to the expressed item (SEAL), likely agent (SHARK), and likely theme (FISH) after verb morphology in (A) Strong bias/Active and (B) Strong bias/Passive trials, and after NP2 in (C) Weak bias/Active and (D) Weak bias/Passive trials. Error bars represent standard errors across children.

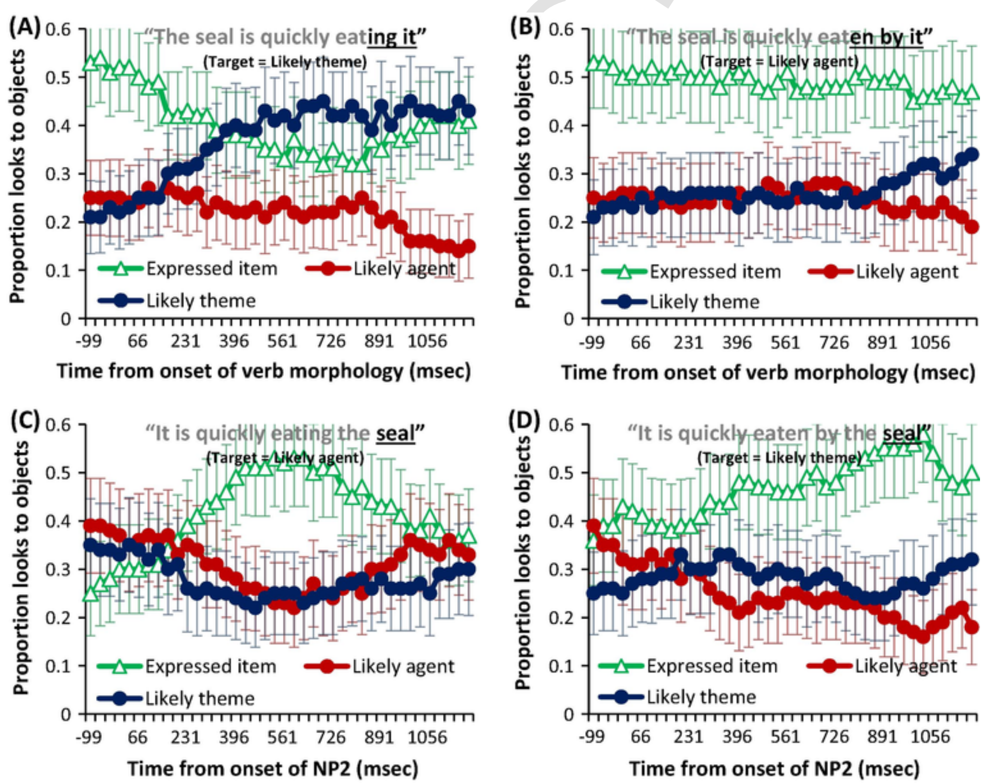

Fig. 4. Among children from lower-SES backgrounds, fixations to the expressed item (SEAL), likely agent (SHARK), and likely theme (FISH) after verb morphology in (A) Strong bias/Active and (B) Strong bias/Passive trials, and after NP2 in (C) Weak bias/Active and (D) Weak bias/Passive trials. Error bars represent standard errors across children.

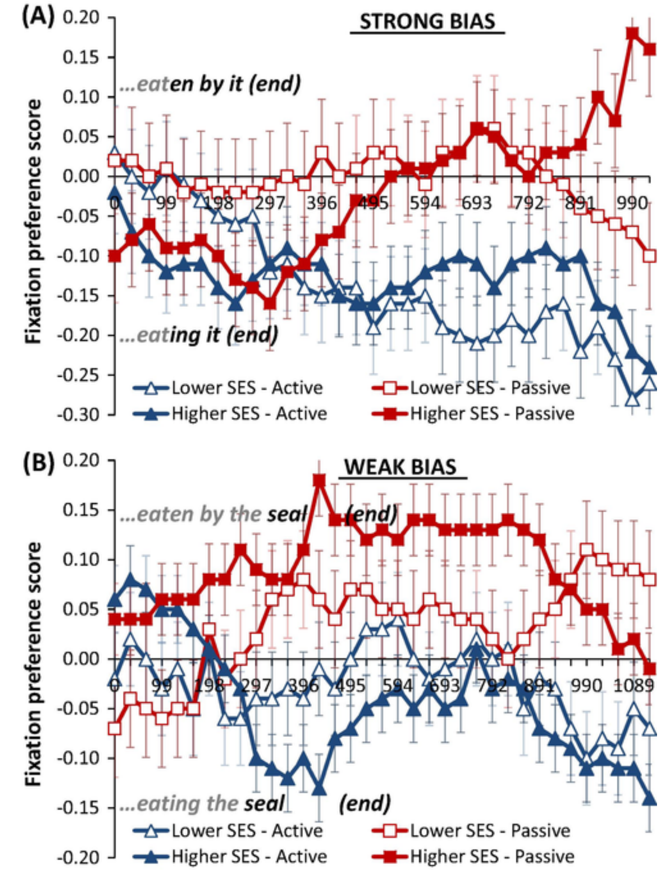

Fig. 5. In fixation analyses, preference scores (A) after verb morphology in the Strong bias condition and (B) after NP2 in the Weak bias condition. Correct fixations to the Target are indicated by positive scores in passive trials and negative scores in active trials. Error bars represent standard errors across children.

jects. Follow-up analyses confirmed that the number of excluded trials did not differ by age, income, or construction type (all z's < 1.50, all *p*'s > 0.10).

As expected, Fig. 5 illustrates greater preference scores in passive trials compared to active trials. Importantly, SES-related differences also emerged. In the Strong bias condition, Target fixations following passives increased for children from higher-SES backgrounds (leading to scores above 0) but remained unchanged for those from lower-SES backgrounds (leading to scores around 0). This led to an interaction between family income and construction type (z = 2.31, $p < 0.05$). Planned comparisons revealed that family income was associated with positive scores for passives (z = 1.37, $p > 0.15$) and negative scores for actives (z = 1.52, $p > 0.10$), but these effects did not approach significance. There was also a marginal effect of family income (z = 1.65, $p < 0.10$), but no main effects of age and construction type (all *p*'s > 0.20). In the Weak bias condition, a similar interaction between family income and construction type emerged (z = 2.63, $p < 0.01$). Here, planned comparisons revealed that family income was associated with significantly more positive scores for passives (z = 1.98, $p < 0.05$) and marginally more negative scores for actives (z = 1.84, $p < 0.10$). There was an additional marginal effect of family income (z = 1.76, $p < 0.10$), but no main effects of age and construction type (all *p*'s > 0.20).

Follow-up analyses directly compared effects of family income and NP1 status within a construction type. For actives, more negative preference scores were found in the Strong bias condition compared to the Weak bias condition, suggesting that processing of active cue was easier when it was consistent with an agent-first bias. This led to a main effect of NP1 status (z = 2.11, $p < 0.05$) with no additional effect of or interaction with family income (all *p*'s > 0.50). In contrast, a significant main effect of family income was found for passives (z = 3.17, $p < 0.01$). Children from higher-SES backgrounds generated more positive scores compared to their lower-SES counterparts, on average. There was no additional effect of or interaction with NP1 status (all *p*'s > 0.15). Taken together, fixation patterns suggest the presence of SES-related effects on real-time syntactic processing. While all children process high-frequency active cues similarly, those from lower-SES backgrounds are less sensitive to low-frequency passive cues compared to their higher-SES counterparts. SES-related differences emerge irrespective of the agent-first bias, suggesting that these effects reflect how input statistics facilitate the retrieval of linguistic cues, independently of the need for syntactic revision.

3.2. Action analyses

To examine how final interpretation varied with condition and SES background, we assessed the likelihood of correct responses in children's actions. Fig. 6 illustrates that overall accuracy was surprisingly low, even in the active trials (approximately 60%). Task complexity likely contributed to this effect. Each sentence included two NPs, an intervening adverb, and a pronoun whose identity had to be inferred based on the linguistic context. Importantly, average accuracy for active sentences was similar across Strong bias (60%) and Weak bias conditions (55%), suggesting that task demands were matched across contexts. Thus, these trials provide an appropriate baseline for the specific challenges associated with passives. Fig. 6 also illustrates that errors with passives often involved role reversals, where children assigned an incorrect role to the definite NP and selected a plausible pronoun referent on this basis. This suggests that failure to revise an agent-first contributed to errors in final interpretation.

In the Strong bias condition, all children were less accurate with passives compared to actives. However, those from lower-SES backgrounds found passives to be more challenging, on average, relative to their higher-SES peers. This led to a main effect of construction type (z = 5.59, $p < 0.001$) and an interaction with family income (z = 2.22, $p < 0.05$). Planned comparisons revealed that family income was associated with significantly higher accuracy for passives (z = 2.07, $p < 0.05$), but only marginally so for actives (z = 1.70, $p < 0.10$). There were also a main effect of age (z = 2.06, $p < 0.05$) but not family income ($p > 0.30$). Importantly, a different pattern emerged in the Weak bias condition. Here, similar accuracy was found across trials and SES background. While there was an overall main effect of age (z = 4.06, $p < 0.001$), there was no effect of family income or construction type (all *p*'s > 0.20).

Follow-up analyses directly compared effects of family income and NP1 status within a construction type. For actives, no significant effects were found (all *p*'s > 0.10). However, for passives, there were main effects of NP1 status (z = 3.66, $p < 0.001$) and family income (z = 4.63, $p < 0.001$) and an interaction between the two (z = 2.19, $p < 0.05$). Planned comparisons revealed that family income was associated with higher accuracy in the Strong bias condition (z = 2.07, $p < 0.05$) but not in the Weak bias condition ($p > 0.50$). Taken together, action patterns suggest that developmental difficulties with passives do not reflect a failure to acquire syntactic structures for a low-frequency construction. If this were the case, then SES-related effects in the Strong bias condition should have also emerged in the Weak bias condition. Their presence in the former but not the latter

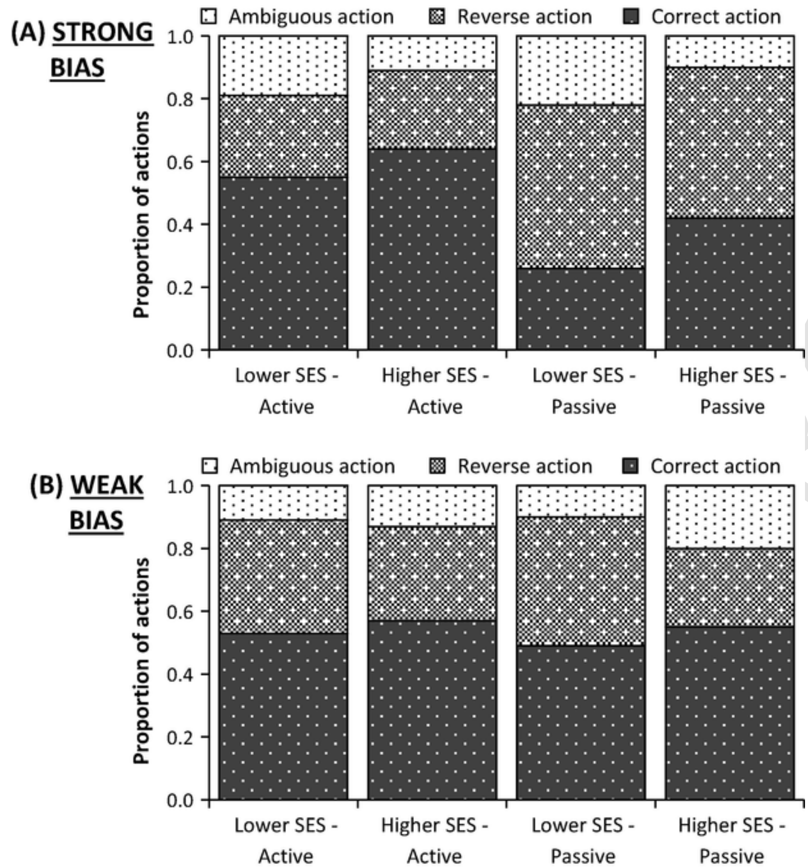

Fig. 6. Proportion of coded action responses for active and passive sentences in the (A) Strong bias and (B) Weak bias conditions.

suggests that language experience impacts how children revise misinterpretations during comprehension, rather than how they learn structures in the first place.

Additional support for this account comes from correlations between on-line sensitivity and off-line accuracy. Recall that on-line sensitivity differed across SES background in both the Strong and Weak bias conditions. To quantify individual differences in on-line sensitivity, we calculated average preference scores for passive minus active trials for each child. This value is greater in children who looked at correct Targets in passive (more positive scores) and active trials (more negative scores). Table 2 illustrates that simple correlations were found between on-line sensitivity and passive accuracy in both the Strong and Weak bias conditions. However, partial correlations revealed that on-line sensitivity continued to predict passive accuracy in the Strong bias condition, even when age, family income, and active interpretation were accounted for. Yet, the same was not true in the Weak bias condition. This suggests that SES-related differences in comprehending passives originate from factors associated with the real-time processing of linguistic cues. Variation in on-line sensitivity minimally impacts final accuracy when a single interpretation is available (Weak bias condition). However, efficient access to representations may be critical when revising prior misinterpretation (Strong bias condition).

Table 2
Correlations between on-line sensitivity (preference scores for passives minus actives) and off-line accuracy with passives (percent correct actions) in the Strong and Weak bias conditions. Partial correlations control for age (in years), family income (dollars per year), and accuracy with actives (percent correct actions).

	On-line sensitivity	
	Strong bias	Weak bias
Actions (passive) *simple correlation*	0.31** (CI: 0.07–0.51)	0.29* (CI: 0.05–0.49)
Actions (passive) *partial correlation*	0.33** (CI: 0.08–0.54)	0.13 (CI: −0.12 to 0.37)

Note. Effects marked with * for $p < 0.05$, ** for $p < 0.01$. CIs indicate 95% confidence intervals.

3.3. Vocabulary analyses

Finally, given the robust associations between SES and vocabulary measures in the current sample (Fig. 2), we examined how syntactic-processing abilities might shed light on possible relationships between these factors. As stated in the Introduction, concurrent measures cannot definitively isolate questions of causation. However, this approach may provide evidence for the routes by which language experience can impact development. In particular, we reasoned that if experience broadly determines what is learned during development, then the same factors that generate SES-related effects of vocabulary size should also promote the acquisition of syntactic structures. This should lead to correlations between vocabulary size and accuracy with passives, irrespective of NP1 status. Yet, it is also possible that language experience impacts vocabulary development through its relationship with syntactic processing. Since children use syntactic cues to bootstrap the meanings of words (Gleitman, 1990), increased challenges with revision may lead to instances of mislearning from caregiver input (Huang & Arnold, 2016). These effects may accumulate over time and lead to individual differences in vocabulary size. If this were the case, then we might expect correlations with vocabulary size to be more robust with passives that require revision compared to those that do not.

Table 3 illustrates that vocabulary size was correlated with the accuracy of active and passive interpretations, age, and family income across levels of NP1 status (all *r's* > 0.30, all *p's* < 0.01). To test the robustness of these relationships, we conducted a series of partial correlations that controlled for effects of age (basic effects of cognitive development) and performance with actives (basic ability to perform the language-processing task). Table 4 illustrates that family income is a broad SES measure that continued to correlate with vocabulary size in the Strong and Weak bias conditions. In contrast, a different pattern emerged with passives. Accuracy in the Strong bias condition continued to correlate with vocabulary size. However, no relationship was found in the Weak bias condition, when other factors were accounted for. This suggests that unlike measures of family income, performance with passives in the Strong bias condition may isolate ways in which syntactic processing can facilitate vocabulary development.[3] Advanced revision abilities may enable more accurate inferences of word meanings based on syntactic cues in the input. Confirmation of this hypothesis awaits future research that examines syntactic processing and vocabulary growth within a longitudinal design.

4. Discussion

This study investigated the sources of SES-related differences in syntactic development by examining the comprehension of active and passive sentences in children from diverse SES backgrounds. In measures of final interpretation, children across all backgrounds used linguistic cues to assign correct roles in actives *and* passives that did not require syntactic revision. However, they were less accurate when passives did require revision, and this was particularly true for children from lower-SES backgrounds, on average. Measures of real-time processing lend additional insight into these patterns. Across contexts, SES-related differences emerged in children's on-line sensitivity to linguistic cues. However, these effects only predicted the accuracy of final interpretation when syntactic revision was needed. Altogether, these results suggest that SES-related differences in language experience facilitate retrieval of syntactic representations during comprehension, enabling accurate interpretation in the face of parsing challenges. Yet, when these challenges are removed, effects of language experience also diminish, revealing strikingly similar comprehension abilities across SES background.

In the remainder of this discussion, we will focus on four additional issues related to the current findings. First, we will consider the extent to which differences in accuracy across NP1 status reflect statistical properties that exist in the input. Second, we will evaluate whether SES-related effects with passives can be explained by cognitive and/or linguistic factors that may vary in children from diverse backgrounds. Third, we will present some very preliminary evidence of what kinds of language experience may be relevant for explaining SES-related differences in interpreting passives. Finally, we will discuss the broader implications of the current findings for theories of language development and language processing.

Table 3
Descriptive statistics and simple correlations (Pearson's r) between tasks and demographics in the (A) Strong bias and (B) Weak bias condition.

	Family income	Action (active)	Action (passive)	Vocab size
(A) Strong bias				
Actions (active) M = 0.60 SD = 0.26 Range = 0–1.00	0.19 (CI: −0.08 to 0.44)	–	–	–
Actions (passive) M = 0.35 SD = 0.31 Range = 0–1.00	0.38** (CI: 0.12–0.59)	0.36** (CI: 0.12–0.56)	–	–
Vocabulary size M = 87 SD = 25 Range = 34–139	0.45** (CI: 0.20–0.64)	0.35** (CI: 0.11–0.55)	0.45** (CI: 0.22–0.63)	–
Age (months) M = 58 SD = 10 Range = 43–86	0.27 (CI: −0.01 to 0.50)	0.25* (CI: 0.01–0.47)	0.30* (CI: 0.06–0.51)	0.64** (CI: 0.46–0.77)
(B) Weak bias				
Action (active) M = 0.56 SD = 0.29 Range = 0–1.00	0.15 (CI: −0.12 to 0.40)	–	–	–
Action (passive) M = 0.53 SD = 0.28 Range = 0–1.00	0.17 (CI: −0.10 to 0.41)	0.61** (CI: 0.43–0.74)	–	–
Vocabulary size M = 86 SD = 29 Range = 2–141	0.62** (CI: 0.42–0.76)	0.43** (CI: 0.20–0.61)	0.32* (CI: 0.08–0.53)	–
Age (months) M = 59 SD = 9 Range = 42–84	0.22 (CI: −0.04 to 0.46)	0.53** (CI: 0.32–0.69)	0.46** (CI: 0.24–0.63)	0.57** (CI: 0.37–0.72)

Note. Effects marked with * for $p < 0.05$, ** for $p < 0.01$. CIs indicate 95% confidence intervals.

Table 4
Partial correlations between vocabulary size (raw PPVT score), family income (dollars per year), and accuracy with passives (percent correct actions) in the Strong and Weak bias conditions, controlling for age (in years) and accuracy with actives (percent correct actions).

	Family income		Actions (passive)	
	Strong bias	Weak bias	Strong bias	Weak bias
Vocabulary size	0.36** (CI: 0.09–0.58)	0.61** (CI: 0.42–0.76)	0.31* (CI: 0.06–0.52)	−0.02 (CI: −0.27 to 0.23)

Note. Effects marked with * for $p < 0.05$, ** for $p < 0.01$. CIs indicate 95% confidence intervals.

4.1. Why are passives sometimes hard to comprehend?

We have argued that definite NP1s introduce challenges for interpreting passives since they promote an agent-first bias that must later be revised. However, it is possible that the current patterns were instead driven by task features that were syntactically or pragmatically infelicitous. Here we consider two versions of this hypothesis. One possibility is that children's challenges with passives were driven by their interpretation of the adverb rather than NP1. Adverbs that encoded manner of motion may be more felicitous with actives, which typically convey on-going events (e.g., "*quickly eating it*"). However, they may be infrequent with passives, which typically convey completed events (e.g., "*quickly eaten by it*"). Moreover, the presence of

[3] Follow-up analyses controlling for family income found weaker correlations between passives and vocabulary size in the Strong bias condition ($r(47) = 0.21$, $p < 0.15$). No effects were found in the Weak bias condition ($r(48) = 0.03$, $p > 0.80$). Since family income entails many SES-related factors that affect development beyond caregiver input (e.g., nutrition, stress), it is unsurprising that associations across language measures decrease when income is included. Power analyses indicate that detecting a significant passive-vocabulary correlation in the Strong bias condition would now require 175 participants but 8718 in the Weak bias condition. On this basis, we believe that these conditions capture distinct processes related to vocabulary development.

manner adverbs in sentences has been shown to increase attention to event actions (Syrett, Arunachalam, & Waxman, 2014), thereby potentially increasing children's agent-first bias.

We see three reasons to reject this account of our data. First, corpus analyses suggest that adverbs, including those that encode manner of motion, are not uncommon with *be*-passives. In an analysis of spoken utterances from the British National Corpus (Aston & Burnard, 1998), McEnery and Xiao (2005) found that adverbs occurred in 19.5% of 5001 instances of *be*-passives. Second, manner adverbs in the current study occurred in the Strong *and* Weak bias conditions. If they are infelicitous in passives, this should have negatively impacted accuracy in both cases. Finally, data from Mandarin passives suggest the agent-first bias is unaffected by the presence of adverbs (Huang et al., 2013). Unlike in English, the BEI marker disambiguates both arguments before the onset of the adverb (e.g., seal BEI it quickly eat → "*The seal is quickly eaten by it*"). Nevertheless, much like in the current study, Mandarin-speaking children were less accurate as using passive cues in contexts with definite NP1s. This suggests that the agent-first bias reflect properties of NP1s and not the presence of adverbs.

A second possibility is that challenges with definite NP1s reflect frequency differences linked to the pragmatics of passives. During communication, passives highlight themes relative to agents (Johnson-Laird, 1968; Williams, 1977), and pronouns refer to prominent discourse entities in topic/subject (NP1) position (Arnold, 2010; Givon, 1983). Thus, relative to actives, we might expect passives to exhibit a greater frequency advantage for pronoun NP1s compared to definite NP1s. To verify this, we found 2467 instances of spoken utterances in the British National Corpus (Aston & Burnard, 1998) that featured properties similar to the current stimuli: (1) transitives with a *be* auxiliary (i.e., NP1 *be* VP-*ing* or VP-*ed by* NP2), and (2) pronouns and definite NPs within a sentence. Among these utterances, Table 5 confirms that speakers are far more likely to produce actives compared to passives (Gordon & Chafetz, 1990; Maratsos et al., 1985; Stromswold et al., 2002), and use pronouns to refer to entities in subject position (Arnold, 2010; Arnold & Griffin, 2007). Thus, if the accuracy of children's comprehension reflected input statistics alone, then frequency-driven challenges for passives compared to actives in sentences with definite NP1s (Strong bias condition) should have led to parallel patterns in sentences with pronoun NP1s (Weak bias condition). Importantly, the absence of such effects suggests that statistical properties alone cannot account for our current patterns.

Interestingly, similar patterns are also found in child production. Brooks and Tomasello (1999) asked 2- and 3-year-olds to generalize novel verbs in active and passive sentences, and their utterances were coded based on NP1 status (note that unlike the analyses above, children sometimes omitted NP1s in their utterances, thus percentages will not add up to 100%). Since production was elicited through question prompts, children generally prefer pronoun NP1s compared to definite NP1s. Critically, this preference was the same across actives (58% vs. 10%) and passives (59% vs. 14%). In a follow-up experiment, the authors used a discourse manipulation to boost overall production of definite NP1s. While actives still favored pronoun NP1s over definite NP1s (45% vs. 29%), passives now featured comparable proportions of both (33% vs. 36%). This pattern is opposite of what would be expected if children generally prefer passives with pronoun NP1s. Altogether, these data suggest that inexperience with definite NP1s in passives cannot account for our current patterns.

Table 5
In a search of adult-directed utterances in the British National Corpus (Aston & Burnard, 1998), the frequency of 2467 instances of *be*-actives and *be*-passives categorized by NP1 status (i.e., NP1 *be* VP-*ing* or VP-*ed by* NP2). Within a sentence, pronoun NP1s appeared with definite NP2s, and definite NP1s appeared with pronoun NP2s.

	Total	Active	Passive
Pronoun NP1	1940 (78.6%)	1803 (92.9%)	137 (7.1%)
Definite NP1	527 (21.4%)	511 (97.0%)	16 (3.0%)

4.2. Why do SES-related differences emerge with passives?

We have argued that SES-related differences in interpreting passives reflect effects of language experience during the real-time processing of syntactic cues. However, it is possible that the patterns we observed were driven by other cognitive and/or linguistic factors that may vary with SES backgrounds. One possibility is that SES-related differences exist in the ability to overcome basic task demands in the current study. Recall that critical trials required children to correctly assign grammatical roles to definite NPs (e.g., is "*the seal*" an agent or theme?) and use this knowledge to select a semantically plausible referent for pronouns (e.g., is "*it*" a fish or shark?). Thus, it may be that our findings do not reveal children's challenges with syntactic revision, but instead reflect SES-related differences in more basic processes, like pronoun interpretation or semantic knowledge of related objects.

Yet, other features of children's performance are inconsistent with this account. We found no SES-related differences in the accuracy of interpreting actives and passives that do not require revision. Like passives that required revision, these trials also involved utterances of a similar length, pronoun interpretation, and real-world knowledge. Perhaps most striking, children correctly inferred the referent of a pronoun NP1 in actives (e.g., "*It is quickly eating the seal*" → "*It*" is a SHARK), despite failing to do so when the same object was the referent of passives that required revision (e.g., "*The seal is quickly eaten by it*" → "*It*" is a SHARK). Moreover, even when children incorrectly interpreted these latter trials, their actions revealed an understanding of the basic task. They depicted far more plausible relationships (e.g., making the SEAL eat the FISH – lower: 57%, higher: 65%) than implausible ones (e.g., making the SEAL eat the SHARK – lower: 12%, higher: 10%), with no differences across SES background (all p's > 0.20). This preference for plausible errors is consistent with failures in syntactic revision and suggests that real-world knowledge is unlikely to account for SES-related differences with passives.

A second possibility is that SES-related differences with passives reflect variation in the cognitive-control abilities that support real-time comprehension. Notable parallels exist between syntactic revision and cognitive-control tasks (e.g., Stroop, n-back), among experienced language users like adults (Hsu & Novick, 2016; January, Trueswell, & Thompson-Schill, 2009; Novick, Hussey, Teubner-Rhodes, Harbison, & Bunting, 2014) and impaired populations like Broca's aphasics (Novick, Kan, Trueswell, & Thompson-Schill, 2010). Late maturation of cognitive-control abilities has been argued to cause developmental challenges with syntactic revision (Mazuka, Jincho, & Onishi, 2009; Novick, Trueswell, & Thompson-Schill, 2005; Woodard, Pozzan, & Trueswell, 2016). Importantly, executive function skills vary with SES backgrounds (Blair et al., 2011; Hackman & Farah, 2009), raising the possibility that the current findings reflect effects of cognitive control and not language experience.

Admittedly, it is difficult to address this account directly since we did not collect separate measures of cognitive control. Moreover, it may not be useful to consider effects of domain-general cognition as being mutually exclusive from those of domain-specific linguistic input, since accounts of language processing typically involve both

(Mazuka et al., 2009; Novick et al., 2005). Indeed, research on bilinguals has highlighted ways in which language experience can shape cognitive-control abilities during development (Bialystok, Craik, Klein, & Viswanathan, 2004; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). Nevertheless, within the current study, asymmetries between on-line and off-line performance suggest that SES-related effects have their basis in how language experience impacts retrieval of syntactic structures. Even when accuracy for passives was equivalent in the Weak bias condition, fixations to correct referents remained delayed among children from lower-SES backgrounds, on average, compared to higher-SES counterparts. This suggests that language experience impacts real-time processing even when no cognitive control is needed for syntactic revision.

4.3. What is the relationship between language experience and language interpretation?

While the current study sheds light on the potential mechanisms underlying SES-related differences in syntactic development, it leaves open what language experiences generate these effects. Future work will pair the language-processing task with direct assessments of caregiver input to tackle this question. Nevertheless, given the current findings, we conducted preliminary analyses to explore the extent to which comprehension of actives and passives may be associated with a proxy of language experience: parental reports of the number of children's books in the home. It is well documented that storybooks are a key source of linguistic input (Montag, Jones, & Smith, 2015) and a strong predictor of language outcomes (Sénéchal, LeFevre, Hudson, & Lawson, 1996). Among our current sample, families owned on average 51 books (SD = 32 books; Range = 0–80 + books). Unsurprisingly, book quantity was strongly correlated with family income ($r(106) = 0.67$, $p < 0.001$) and school status ($r(112) = 0.71$, $p < 0.001$).

Notably, when book quantity was added as a predictor of comprehension accuracy, its effects emerged specifically in the Strong bias condition, and varied with family income and construction type ($z = 2.17$, $p < 0.05$). To unpack this three-way interaction, we divided our sample into two SES groups (see Section 3 for details) and correlated book quantity with accuracy in each condition, while controlling for age. In the passive trials, book quantity was positively associated with accuracy for children from higher-SES families ($r(24) = 0.26$, $p > 0.15$), but this did not approach significance. No relationship was found for their lower-SES peers ($r(23) = -0.03$, $p > 0.80$). In contrast, in the active trials, book quantity was positively associated with accuracy for children from lower-SES families ($r(23) = 0.46$, $p < 0.05$). Curiously, this relationship did not emerge for their higher-SES counterparts ($r(24) = 0.12$, $p > 0.50$). Thus, consistent with prior work, these patterns confirm that language experience (as measured by book quantity) is related to language outcomes (as measured by comprehension accuracy).

However, they also suggest that these relationships are likely more complex than a simple frequency effect (e.g., more input always boosts the number of passives heard). Instead, input quantity may interact with differences in the structures produced by caregivers from varying SES backgrounds (Huttenlocher et al., 2007, 2010). Among higher-SES families, greater input may be associated with an increased frequency of passives, and may contribute to the relationship between input quantity and passive comprehension found above. In contrast, among lower-SES families, greater input may be associated with an increased frequency of actives, thus generating a relationship between input quantity and active comprehension. These effects may also contribute to recent evidence that children from higher-SES backgrounds prefer to learn from informants who produced passive sentences, while their lower-SES counterparts prefer informants who produced active sentences (Corriveau, Kurkul, & Arunachalam, 2016).

Clearly, these patterns will need to be confirmed with direct measures of caregiver input. However, to the extent that they prove reliable, it suggests that the statistical profiles of syntactic structures associated with increased input may vary across SES background. This has direct implications for current interventions that focus on increasing caregiver input among lower-SES families (e.g., 30 Million Words Initiative, Providence Talks). Such approaches may improve comprehension of constructions that are already frequent in the input, but they may be less effective for addressing SES-related differences in complex/infrequent syntactic structures.

4.4. Implications for theories of language development and language processing

By examining variation during development through the lens of real-time processing, the current findings inform theories of language in multiple domains. With respect to acquisition, this study provides surprising evidence of early proficiency with a low-frequency construction. This pattern is consistent with prior work in Mandarin (Huang et al., 2013). As in English, BEI passives occur less frequently than BA actives. Moreover, cross-linguistic comparisons suggest that passives are ten times less frequent in Mandarin than in English (McEnery & Xiao, 2005). Yet, when syntactic revision was not required, children's accuracy with passives did not differ from actives. This parallels current findings on SES-related effects on passives, which are rare in caregiver input (Gordon & Chafetz, 1990; Maratsos et al., 1985; Stromswold et al., 2002) and perhaps even more so among lower-SES families. Critically, we found no SES-related effects on ultimate interpretation of passives that did not require revision. This suggests that children can acquire knowledge of syntactic constructions, even when input is minimal.

Importantly, our findings suggest that even while learning constructions may be quick, mastering comprehension may be remarkably slow. Despite their accuracy with passives that do not require revision, children – particularly those from lower-SES backgrounds – were far less successful when revision was necessary. Correlations between on-line fixations and off-line accuracy suggest that individual differences in the retrieval of structures mediate variation in syntactic revision. Relative to higher-SES peers, children from lower-SES backgrounds were less sensitive to linguistic cues in utterances, and this created specific challenges when interpreting passives that required retrieval of alternative structures to revise an agent-first bias. Moreover, the absence of SES-related effects on actives suggests that properties of the initial analysis likely play a minimal role in the current test case. After all, if children from lower-SES backgrounds had a stronger agent-first bias, then they should have also had accuracy with utterances that favor this bias, compared to their higher-SES counterparts. Finally, challenges with syntactic revision are not isolated to languages where passive cues have low validity. While the past participle is associated with the past tense and the *by*-phrase marks locations in English, BEI unambiguously signals passives in Mandarin. Yet, despite its high cue validity, Mandarin-speaking children faced challenges interpreting passives that require revision (Huang et al., 2013), much like their English-speaking counterparts.

However, the current study leaves unanswered what input statistics shape syntactic-revision abilities. Since developmental difficulties span multiple constructions (Choi & Trueswell, 2010; Huang et al., 2013; Hurewitz et al., 2000; Omaki et al., 2014; Trueswell et al., 1999; Weighall, 2008), many have appealed to non-linguistic causes such as cognitive control (Mazuka et al., 2009; Novick et al., 2005; Woodard et al., 2016). However, adult syntactic processing occurs within a highly interactive system (Gibson et al., 2013; Levy, 2008; Levy et al., 2009; MacDonald et al., 1994; Trueswell & Tanenhaus, 1994), thus broad patterns may also reflect statistical computations across multiple levels: constructions (e.g., passives), subclasses (e.g., *get*- or *be*-passives), grammatical roles (e.g., when NP1s aren't canonical agents). SES-related differences in caregiver input may provide a window into how these levels interact during development. Within passives, there is a dialect preference for *get*-passives over *be*-passives among lower-SES adults (Sneller, 2015; Weiner & Labov, 1983). Thus, while children from higher-SES families show a relative advantage for revising *be*-passives, it is possible that their lower-SES peers may reveal an advantage for *get*-passives. Moreover, if frequent encounters with non-canonical constructions (e.g., passives, object relative clauses, *wh*-questions) generally facilitate access to structures where NP1s are not agents, then SES-related differences along this dimension may also predict revision abilities. Importantly, asking these questions in the first place requires a unified framework that captures fundamental relationships between learning and processing across the lifespan.

5. Conclusion

This study examined the role of SES background on syntactic processing of spoken utterances in 3- to 7-year-olds. Fixation patterns revealed average SES-related differences in real-time sensitivity to linguistic cues distinguishing active and passive sentences. Decreased sensitivity generated specific challenges for interpreting passives that required syntactic revision (e.g., *re*interpreting "*the seal*" as the theme after hearing "… *eaten by it*"), leading to SES-related differences in the final interpretation of utterances. Importantly, we found that all children were equally proficient with passives that did not require revision (e.g., interpreting "*it*" as the theme after hearing "… *eaten by the seal*"), suggesting that language experience did not alter the ability to acquire structures for passives in the first place. Altogether, these results suggest that SES-related differences are present in real-time syntactic processing, and variation along this dimension impacts the accuracy of utterance interpretation.

Acknowledgments

We are grateful to Lauren Abadie, Erin Hollister, and other members of the Language and Cognition Lab for their assistance in data collection and coding. We would also like to thank the families and administrators at the Meade Village Head Start Program (Anne Arundel County, MD), Azeeze Bates Head Start Program (Washington, DC), and Tubman Head Start Program (Columbia, MD) for taking part in this study. This work has benefited from insightful conversations with Rachael Richardson, Jeff Lidz, and Jan Edwards. Portions of this work have been presented at the 41st annual Boston University Conference for Language Development. This work was supported by an NSF IGERT fellowship to KL and a UMCP ADVANCE grant to YTH and MR.

Appendix A

Sentences and objects on critical trials of the language-processing task.

	Condition	Sentence (active/passive)	Expressed item	Agent	Theme
1	Strong bias	The boy is gently kicking/ kicked by it	BOY	HORSE	BALL
	Weak bias	It is gently kicking/kicked by the boy			
2	Strong bias	The towel is gently cleaning/ cleaned by it	TOWEL	DRYER	PAN
	Weak bias	It is gently cleaning/cleaned by the towel			
3	Strong bias	The firefighter is quickly rescuing/rescued by it	FIREFIGHTER	HELICOPTER	CAT
	Weak bias	It is quickly rescuing/rescued by the firefighter			
4	Strong bias	The girl is happily feeding/fed by her	GIRL	MOTHER	BABY
	Weak bias	She is happily feeding/fed by the girl			
5	Strong bias	The rabbit is slowly eating/ eaten by it	RABBIT	WOLF	CARROTS
	Weak bias	It is slowly eating/eaten by the rabbit			
6	Strong bias	The seal is quickly eating/ eaten by it	SEAL	SHARK	FISH
	Weak bias	It is quickly eating/eaten by the seal			
7	Strong bias	The dog is slowly chasing/ chased by it	DOG	CAR	RABBIT
	Weak bias	It is slowly chasing/chased by the dog			
8	Strong bias	The girl is tightly hugging/ hugged by her	GIRL	MOTHER	BABY
	Weak bias	She is tightly hugging/hugged by the girl			
9	Strong bias	The frog is quietly catching/ caught by it	FROG	DOG	FLY
	Weak bias	It is quietly catching/caught by the frog			
10	Strong bias	The boy is carefully lifting him up/lifted up by him	BOY	DAD	BABY
	Weak bias	He is carefully lifting the child up/lifted up by the child			
11	Strong bias	The rock is loudly smashing/ smashed by it	ROCK	HAMMER	EGG
	Weak bias	It is loudly smashing/smashed by the rock			
12	Strong bias	The cat is easily scaring/ scared by it	CAT	DOG	MOUSE
	Weak bias	It is easily scaring/scared by the cat			

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2016.11.004.

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