# The Role of Verb-Event Structure in Children's Lexical Ambiguity Resolution

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**Abstract**

Recent evidence indicates that children represent and learn multiple meanings of ambiguous words from early in development (e.g., mail letter, alphabetic letter). This raises the question of which naturalistic factors might allow young children to resolve lexical ambiguities. Previous research has shown that children's processing of ambiguous words is facilitated by verb-related information. However, it is still unclear whether such facilitation comes from bottom-up (lexical associations) or top-down information sources (verb-event structures). In this study, we leveraged a large sense-annotated child-directed speech corpus to disentangle the effect of bottom-up lexical and top-down event structure cues. Preliminary results show that 4-year-olds might rely on verb-event structures when these are put in competition with lexical association. We discuss implications for theories of sentence parsing and word learning.

**Keywords:** lexical ambiguity resolution; language development; verb-event structure

## Introduction

The words that children hear are often ambiguous in isolation (e.g., *chicken* can refer to a type of food or a type of animal), but the contexts in which words appear guide children in resolving lexical ambiguities (e.g., Khanna & Boland, 2010; Rabagliati et al., 2013). In this work, we examined the role of verbs in children's lexical ambiguity resolution.

Verbs are an important source of disambiguating information for ambiguous nouns (Hahn et al., 2015; Rabagliati et al., 2013); for example, after hearing the phrase *eat the chicken*, a child is likely to interpret the noun *chicken* as referring to a type of food. But while we know that verbs facilitate children's interpretation of ambiguous words, it is still unclear whether such facilitation operates in a top-down or a bottom-up manner, because bottom-up and top-down cues are often entangled in naturalistic contexts (e.g., Ambridge et al., 2015). In the example above, the verb *eat* might prime the target meaning *chicken[food]* via lexical association (i.e., working as a bottom-up cue to ambiguity resolution); alternatively, the semantic restrictions imposed by the verb *eat* on its arguments (verb-event structure) might guide top-down inferences to suppress contextually irrelevant meanings (e.g., upon hearing *eat the chicken*, the child may infer that *chicken* refers to a type of food because inanimate entities are more plausibly eaten than animate entities).

In this work, we leveraged a large sense-annotated corpus of child-directed speech (ChiSense-12, Cabiddu et al., 2022) to carefully construct experimental stimuli and examine the effect of bottom-up and top-down verb-related cues in early lexical ambiguity resolution. Understanding the role of different types of cues is important for theories of early sentence parsing, some of which emphasize children's reliance on bottom-up cues (Snedeker & Yuan, 2008), while others propose that children consider both bottom-up and top-down cues (Trueswell & Gleitman, 2007). Further, it is key to understanding the learning mechanisms that might underlie sensitivity to different cues in language development (e.g., domain-general processes assumed to cause early sensitivity to verb-event structures, Alishahi & Stevenson, 2007).

In the next sections, we briefly review previous studies on the role of context in early lexical ambiguity resolution, and then present our experimental work aimed at examining the effect of lexical association and verb-event structure on children's comprehension of ambiguous words.

### The Role of Context

Children's lexical ambiguity resolution during conversation is partly dependent on their ability to parse sentences and integrate multiple cues that the sentence context provides. If a child's immature comprehension system presents processing constraints, she will only be able to parse sentences by using those cues that depend on fewer aspects of linguistic analysis (bottom-up account; Snedeker & Yuan, 2008). Such cues are generally those coming from a bottom-up information source. For example, consider the homophones *guest* and *guessed* (/gɛst/). If children generate top-down inferences based on sentence context, when they hear *The house is clean because we expect a guest*, they should activate the congruent meaning *guest*, but not the incongruent *guessed*. Thus, they should subsequently find it easier to repeat the word *room* (which is a frequent lexical associate of *guest*), compared to hearing a context that is only compatible with the alternative meaning (e.g., *Molly didn't know the answer, so she guessed*). However, in Khanna and



In J. Culbertson, A. Perfors, H. Rabagliati & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual Conference of the Cognitive Science Society.* 

Boland (2010), 7-year-olds showed the same facilitation from both *The house is clean because we expect a guest* and *Molly didn't know the answer, so she guessed* (compared to a completely unrelated sentence), suggesting that, although children were sensitive to the lexical association between /gɛst/ and *room*, they were not able to integrate top-down information from the sentence context.

Although such evidence seems to suggest that children struggle to integrate top-down information, another study from Rabagliati et al. (2013) found that 4-year-olds use sentence global plausibility to resolve lexical ambiguities. For example, upon hearing the sentence *Elmo watched a funny movie about a castle, and a princess, and a silly dragon. That was a funny night*, they tend to select a picture depicting *night* (rather than one of a *knight*) more than when the sentence ends in *And there was a funny knight*. Even if words like *castle*, *princess*, *dragon* and *knight* frequently co-occur in naturalistic speech, children were able to integrate top-down information and infer that people usually watch movies at *night*. Therefore, children are sensitive to top-down cues, at least when integrating these cues allows them to derive an interpretation that is more plausible given the wider context (cue-validity account; Trueswell & Gleitman, 2007). Importantly, however, in Rabagliati et al. (2013) children still relied more on lexical associations than on global plausibility: even if a difference was found between the above conditions, children still selected *knight* more than 50% of the time in every condition.

In this study, we directly compare children's reliance on bottom-up vs. top-down cues when the plausibility of the interpretations they support is equated. Specifically, we contrasted different types of verb-related cues. Verbs play a key role in early sentence parsing. For example, the type of syntactic arguments that verbs take guide children's interpretation of ambiguous sentences (e.g., Kidd & Bavin, 2005; Snedeker & Trueswell, 2004; Yacovone et al., 2021). To illustrate, 3- to 5-year-old children interpret the phrase *tickle the bear with the mirror* as *tickle the bear using the mirror* (even if two bears are shown, one of which is holding a mirror) because the verb *tickle* frequently co-occurs with instrument arguments in naturalistic speech (Yacovone et al., 2021). More relevant to the present work, verb-event structures guide children's unambiguous word processing (Andreu et al., 2013; Mani et al., 2016). For example, 3-year-olds know that *pushing a flowerpot* is more plausible than *pushing a road* even if they have never heard either in conversation (Andreu et al., 2013).

In sum, verbs might represent a valid cue that young children could rely on when processing ambiguous words. Although some studies have investigated the role of verbs in early lexical ambiguity resolution (Hahn et al., 2015; Rabagliati et al., 2013), they have not examined the independent contribution of verb lexical associations and verb-event structure. In other words, stimuli used in previous studies included verbs that were both lexically associated with a target sense and licensed the target sense as a plausible argument: in *Karl met the star*, the verb *meet* is likely to co-occur more often with *star[famous person]* than *star[astronomical object]* in the language, and at the same time one more plausibly *meets* an animate entity than an inanimate one (Hahn et al., 2015).

In this experiment, we used a large sense-annotated corpus of child-directed speech to design experimental materials which could disentangle the contribution of bottom-up lexical association and top-down verb-event structure. Given the prominent role of lexical association in lexical ambiguity resolution (Khanna & Boland, Rabagliati et al., 2013) and of verb bias in syntactic ambiguity resolution (e.g., Kidd & Bavin, 2005; Snedeker & Trueswell, 2004; Yacovone et al., 2021), we would expect verbs to facilitate children's performance when the unique cue available is verb lexical association, but it is an open question whether children would be sensitive to this bottom-up cue when verb plausibility does not help.

Further, given the role of verb-event structure in early unambiguous word processing (Andreu et al., 2013; Mani et al., 2016), we would expect a strong effect of this top-down cue, but empirical evidence is needed to examine whether this would be the same for ambiguous word processing.

## Method

### Experiment Overview

We designed an online forced-choice task similar to Rabagliati et al. (2013). Participants heard spoken stories that ended with a target ambiguous noun (see Figure 1). Two seconds before story onset, four pictures appeared on the screen and stayed on until a picture was selected. After hearing the story, participants were asked to select a picture that corresponded to the last word of the story. In each trial, 2 pictures depicted the two senses of a target ambiguous word (the frequent dominant meaning and the subordinate less frequent meaning) (e.g., *band[object], band[music group]*). The other 2 pictures depicted distractor words semantically related to these senses, which were also good completions of experimental stories and frequency-matched to target senses based on the sense-annotated corpus statistics. Participants also initially saw 3 training trials, with spoken stories ending with unambiguous target words (e.g., *Emily went to the shop. Then, she bought a banana*).

Following Rabagliati et al. (2013), we constructed the experimental stories in a way that would allow us to examine whether children use top-down event structure cues when these are put in competition with bottom-up cues (i.e., to exclude the possibility that children use top-down cues only when these are the only ones available in context). Therefore, we constructed stories comprising a prior context and a target context. The prior context always contained words that frequently co-occurred with the target subordinate sense in child-directed speech. For example, in Figure 2, the prior context *Sophia listened to some music* contains the words *listen* and *music* which frequently co-occur with the subordinate meaning *band[music group]*.

The target context was manipulated in 3 within-subject

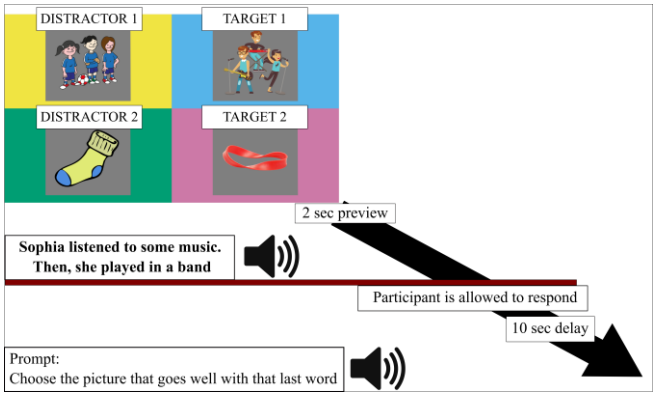


Figure 1: Example of control trial. Participants saw a 2x2 grid depicting 2 target word senses (dominant: *band[object]*; subordinate: *band[music group]*), and two distractor words (*sock*, *team*). Pictures appeared in random locations on every trial. After 2 seconds from picture presentation, the spoken story was played. Participants were allowed to respond when the story ended.

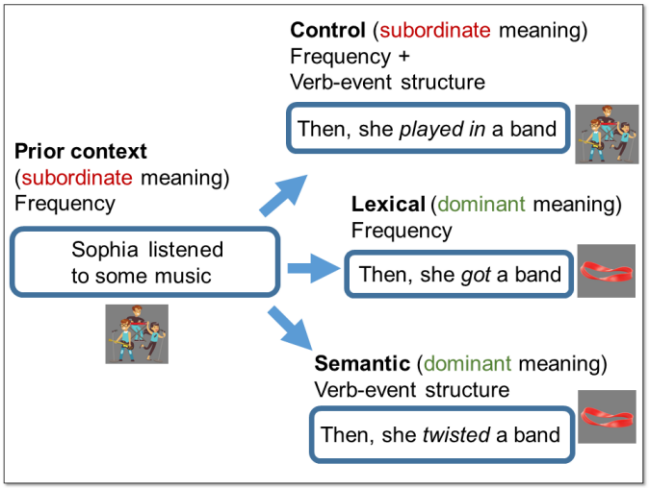


Figure 2: Example of conditions involving the target word *band*. Participants could see a prior context either followed by a control, lexical, or semantic target context.

conditions. In the control condition, the main verb pointed toward the target subordinate sense (i.e., the same sense that was favored by the prior context), both in terms of lexical associations in child-directed speech and plausibility based on verb-event structure. For example, in *Then, she played in a band* (see Figure 2), the verb *play in* is lexically associated to *band[music group]* in child-directed speech and one more plausibly plays in a music band than an elastic band. Specifically, we defined verb-sense lexical association by weighting the raw frequency of verb-sense occurrence by the number of times the sense appeared in the corpus as an object of a verb.

In the lexical condition, the main verb was lexically associated to the dominant target sense (*get* frequently co-occurs with *band[object]* in child-directed speech; see Figure 2), therefore competing with bottom-up cues from the prior context (which pointed toward the subordinate target sense *band[music group]*). Importantly, verb-event structure information was compatible with both target senses in this condition (i.e., one can either *get* a *band[object]* or *band[music group]*). Conversely, in the semantic condition, there was no lexical association between the main verb and either the dominant or subordinate sense. However, the verb only accepted the dominant sense as a plausible object (i.e., one can only *twist* a *band[object]*).

Given the competition between cues from the prior and target context, in the lexical and semantic conditions one must make a higher number of inferences to link the two contexts (e.g., *Sophia listened to some music. Then, she twisted a band*) than in the control condition. Therefore, with the intent of weakening the link between contexts in the control condition as much as possible, we lowered the coherence of all stories. We used a temporal connective (*Then*) which is considered the lowest level of conceptual coherence save for completely unrelated sentences (see Connell & Keane, 2004; compare the control story *Sophia listened to some music. Then, she played in a band* to the alternative *Sophia wanted to create music, so she played in a band*).

## Participants

83 adults were recruited from the platform Prolific (*age*: *M* = 23 years, *SD* = 5 years; 62 female). Data from one adult were discarded for failing more than 1 out of 3 training trials. 20 English-speaking children from 48 to 59 months of age were recruited (*age*: *M* = 54 months, *SD* = 3 months; 3 female, 4 male, 8 third gender, 6 prefer not to say). Data from 5 children were discarded (2 fussiness; 2 failed training; 1 language impairment). Child data collection is ongoing until a sample between 42 and 84 participants is reached. Estimated sample size and data collection stopping rule were defined after carrying out a series of pre-registered power analysis simulations (see https://osf.io/a293m/?view_only==73b7fdb649ef42e0ab943d198b788c5c). Therefore, we only present preliminary results for children. This research project has been approved by the ethics committee of the School of Psychology of Cardiff University.

## Materials

We used the sense-annotated child-directed speech corpus ChiSense-12 (Cabiddu et al., 2022) to construct the experimental stories (see Table A1). The corpus contains 53 corpora of American and English child-directed speech from the CHILDES database (MacWhinney, 2000). The corpora include speech directed to 958 target children of age up to 4 years (59 months). In the corpus, 15,581 utterances (*word tokens* = 115,272; *word types* = 4,805) were tagged for dominant and subordinate meaning of 12 ambiguous words (see Table 1) for which children have shown understanding in previous investigations. Specifically, 11/12 words and their word senses were taken from Rabagliati et al. (2013), while an additional word (/ˈflaʊə/: flower/flour) was chosen

for having relatively frequent senses in CHILDES, with its dominant meaning being known by children from around 20 months of age (Frank et al., 2017).

Additionally, to ensure that all senses in the study were known by children, we asked caregivers to fill in a questionnaire where they could indicate whether a target sense or context verb was *not understood*, *understood*, or *understood and used* by children. We excluded 23% of trials for which a caregiver indicated the child did not know a target sense or context verb (although note that we obtained the same results when including the full sample of trials).

We also asked adults to name each picture used in the experiment. Given that we matched target and distractor pictures by frequency, we ensured that adults spontaneously named the distractors (not spoken in the stories) using the labels we used for the frequency matching (e.g., when matching *chicken* with the distractor *crow*, we ideally want the latter image to be named as *crow* by participants and not as *bird*). For every distractor, the expected label was always the most frequently reported, and was used by 89% adults on average (*SD* =15%).

ChiSense-12 was also tagged for verb stems that take ambiguous senses as object arguments. This allowed us to construct the experimental stories by computing frequencies of co-occurrence between verbs and target senses (see Table A1).

## Procedure

Adults completed the task independently online. Children's online task was identical to the one completed by adults (see Experiment Overview), but an experimenter supervised the sessions because children were asked to give verbal responses (i.e., to say the color of the picture background, see Figure 1). The presence of the experimenter was also to ensure that caregivers would not interfere in child responses and that children would stay engaged in every trial.

Each participant in the experiment saw 4 control stories, 4 lexical stories and 4 semantic stories (all in randomized order), and assignment of stories to conditions was counterbalanced across participants (see Table A1).

## Statistical Analyses

We fit mixed-effect logistic regression models separately to adults and children's data. We used sense choice (dominant, subordinate) as the dependent variable, and condition as the independent variable (control, lexical, semantic). We specified two contrasts: control vs. lexical, control vs. semantic. For adults, the random effect structure of the model included random intercepts for participant and item, and random slopes of condition per participant and item (excluding estimated correlations between item intercepts and slopes). This random effect structure was the one that allowed the model to converge and for which our simulations indicated sufficient and stable power to detect effect sizes of interest.

For children, we report results from a model with the same fixed and random effect structure. However, note that power was simulated for a minimum of 42 participants, therefore results from this model should be taken with caution as they might be underpowered.

Table 1: 12 ambiguous words used in the study. *Dominance* refers to the percentage of time a dominant meaning appeared in the corpus (out of total dominant and subordinate meaning occurrences).

| *Word* (Dominant/Subordinate) | *Dominance* |
|---|---|
| **Band** (Object/Music Group) | 75% |
| **Bat** (Animal/Object) | 66% |
| **Bow** (Knot/Weapon) | 89% |
| **Button** (Electronic/Clothing) | 67% |
| **Chicken** (Animal/Food) | 61% |
| **Flower/Flour** | 91% |
| **Glasses** (Eye/Drinking) | 52% |
| **Letter** (Alphabet/Mail) | 60% |
| **Line** (Geometric/Row) | 66% |
| **Moose/Mousse** | 81% |
| **Nail** (Finger/Tool) | 81% |
| **Sun/Son** | 85% |
| *MEAN* (*SD*) | 73% (13%) |

## Results

As can be seen in Figure 3, adults and children selected the *subordinate* meaning 96% and 54% of the time respectively in the control condition. Participants were able to integrate the sentence context to disambiguate the (subordinate) meaning of the target word.

An opposite pattern of responses, compared to the control condition, can be seen for adults and children in the semantic condition. Here, participants selected the *dominant* sense 88% and 68% of the time respectively. This suggests that they were able to integrate verb-event structures to select the dominant sense of the target words. The difference in performance between control and semantic conditions was significant for both adults (*Odds Ratio* = 759.56 [231.61, 2491.00], $p < .001$) and children (*Odds Ratio* = 5.94 [2.34, 15.12], $p < .001$).

Further, adults and children responded differently to each other in the lexical condition. Adults mostly relied on prior context (65% *subordinate* meaning selection) while children relied on verb-sense lexical association instead (62% *dominant* meaning selection).

In other words, when verb-event structure cues in the target context were neutral, adults preferred to rely on the global plausibility of the story based on the lexical associates included in the prior context (i.e., even if prior and target contexts were not strongly related in terms of coherence, still in *Sophia listened to some music. Then, she got a band* adults selected *band[music group]* because the speaker talked about *music*).

Children, instead, relied on the lexical association between verb and dominant sense in the language (speakers often talk about *getting* a *band[object]* in real-world contexts). This

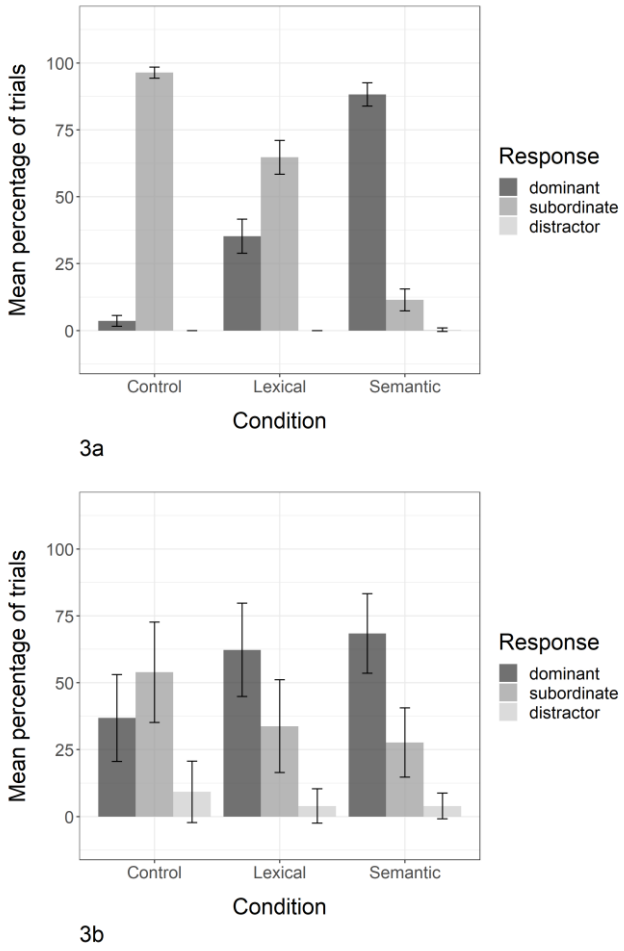


Figure 3: Mean percentage of trials in which adults (3a) and children (3b) selected dominant, subordinate or distractor picture by condition (control, lexical, semantic). Error bars show 95% confidence intervals corrected for within-subject variance.

result is in line with studies which showed children's reliance on verb lexical associations in sentence parsing (e.g., Kidd & Bavin, 2005; Snedeker & Trueswell, 2004; Yacovone et al., 2021).

Interestingly, the difference in performance between control and lexical conditions was significant not only for children (*Odds Ratio* = 4.60 [1.56, 13.53], $p = 0.006$), but also for adults (*Odds Ratio* = 25.29 [9.00, 71.05], $p < .001$), in line with adults' sensitivity to verb-patient lexical associations in studies where they are presented with (unambiguous) thematically appropriate patients of a verb differing in their strength of association to the verb (Andreu et al., 2013; Mani et al., 2016). To investigate this, we computed Kendall Tau partial correlation between verb-sense lexical association and proportion of dominant sense choice, controlling for dominant sense relative frequency. We found moderately strong observed correlations for both adults (*Tau* ($N$=12) = .43, $p = 0.065$) and children (*Tau* ($N$=12) = .44, $p = 0.061$). Also, partial correlations between dominant sense frequency and dominant sense choice (when controlling for verb-sense lexical association) were smaller for both adults (*Tau* ($N$=12) = .32, $p = 0.171$) and children (*Tau* ($N$=12) = .16, $p = 0.486$). This suggests that performance in the lexical condition was driven by our manipulation of verb lexical associations (for both adults and children) and not only by the frequency of dominant target senses in the language.

## Discussion

In this study, we leveraged the large sense-annotated corpus ChiSense-12 (Cabiddu et al., 2022) to construct experimental stimuli that could allow us to examine whether children can integrate bottom-up verb lexical and top-down verb-event structure cues to resolve lexical ambiguities. Adults and 4-year-olds used verb-sense associations to process ambiguous words, although adults showed higher reliance on sentence global plausibility inferred from prior context associations. Importantly, we found the first preliminary evidence that young children might rely on top-down verb-event structure cues to resolve lexical ambiguities, when these are put in competition with bottom-up cues from prior context (and verb-sense association cues are unavailable), supporting a cue-validity account of sentence parsing (Trueswell & Gleitman, 2007).

Previous studies have found that children struggle to integrate top-down global plausibility and mostly rely on a bottom-up cue like lexical association (Khanna & Boland, 2010; Rabagliati et al., 2013). Instead, in our study we found that children relied on verb-event structure to resolve lexical ambiguities, being able to override the effect from prior context associations. If confirmed, the different outcome of our study compared to previous ones could be explained in two ways. One possibility is that given their prominent role in early language processing (e.g., Andreu et al., 2013; Kidd & Bavin, 2005; Mani et al., 2016; Snedeker & Trueswell, 2004; Yacovone et al., 2021), verbs might be considered a more reliable source of information by children compared to other top-down cues. Alternatively, verbs might not have a higher status compared to other top-down cues, but methodological differences might have allowed us to highlight the effect of top-down cues. Namely, in the study from Rabagliati et al. (2013) longer stories preceded the target ambiguous words, which could have provided children with stronger evidence from a larger number of lexical associates in the prior context. Therefore, future studies should examine how the effect of verb-event structure changes as a function of length of prior context. In contrast, age differences are unlikely to account for differences between our findings and those of previous studies (Rabagliati et al. (2013) tested 4-year-olds, as we did).

Sensitivity to prior context might also explain the fact that children mostly selected the dominant sense in the lexical condition, while adults privileged the subordinate sense. In adults, few lexical associates in the prior context might be enough to raise activation of the subordinate sense, while children might need more evidence (i.e., longer sentences) to

activate the subordinate sense via bottom-up associations. In a preliminary follow-up analysis, we aggregated data from adults (*N*=83) and a larger sample of children (*N*=45) (the child pilot data was too sparse for this additional analysis; importantly, the main findings for children reported above and based on the pilot sample were confirmed by analyses looking at the larger sample). We fitted a mixed-effects model with sense choice in the lexical condition (dominant/subordinate) as the outcome, and age group (adult/child), relative frequency of dominant sense (dominance), verb-sense association, and prior context associations as predictors (including two-way interactions between predictors, and three-way interactions between age group and every pair of continuous predictors). Prior context associations were obtained by taking all the words in the prior context and averaging their relative frequency of occurrence in child-directed sentences which contained the target subordinate sense[1]. We found a main effect of verb-sense association (*Odds Ratio* = 1.78 [1.25, 2.55], $p$ = .001), indicating that both adults and children were sensitive to this cue in the lexical condition (see Figure A1). Further, we found a significant interaction of prior association and dominance (*Odds Ratio* = 0.55 [0.38, 0.80], $p$ = .002), and an interaction between age group and dominance (*Odds Ratio* = 0.38 [0.21, 0.67], $p$ = .001). We visually examine these two interactions in Figure A2, where we plot percentages of dominant sense choice as a function of prior association and dominance, for adults and children. In line with the first interaction, one can see that both adults and children are sensitive to prior association to the same extent, although only at high levels of dominance. This is due to a positive correlation between prior association and dominance in the experimental stories (*Spearman rho* = .18) by which the contrast between low and high prior association tends to be more pronounced at high levels of dominance, with the consequence that at low levels of dominance prior association shows no effect (across age). Also, at low levels of dominance child performance is at ceiling (i.e., they almost always select the dominant meaning) while adult performance is at floor (i.e., they almost never select the dominant meaning, in line with the second interaction found). This could indicate higher sensitivity of children to sense dominance. Alternatively, dominance computed on child-directed speech might not accurately reflect sense dominance in adult-directed speech. In any case, this exploratory analysis suggests that differences between child and adult performance in the lexical condition are not due to children requiring exposure to more bottom-up lexical associates in order to activate the subordinate meaning of an ambiguous word.

Finally, is it possible that children's sensitivity to dominance could have helped them select the dominant meaning in the semantic condition, regardless of their knowledge of verb-event structure cues? To examine the role of sense dominance, we fitted an exploratory mixed-effects model including sense choice in the semantic condition as the dependent variable, with age group (adult/child), prior association and sense dominance as predictors (including two-way and three-way interactions). We found no effect of sense dominance (*Ratio* = 0.87 [0.37, 2.05], $p$ = 0.758) nor prior associations (*Odds Ratio* = 0.87 [0.36, 2.13], $p$ = 0.763), suggesting that adults and children likely relied on verb-event structures to disambiguate the target words. To examine this further, we fitted an additional mixed-effects model on child data only, using sense choice in the semantic condition as the outcome, with prior association, sense dominance and verb production (*Not produced* = Not used *or* Understand only; *Produced* = Understand *and* Use) as predictors (including two-way interactions). Verb production was inferred from our parent-report questionnaire. Interestingly, Verb production was the only significant predictor in this model (*Odds Ratio* = 3.50 [1.09, 11.25], $p$ = 0.035), with children being more likely to select the dominant meaning if parent reported production of the preceding verb (see Figure A3). This represents preliminary, suggestive evidence that children indeed relied on their knowledge of verb-event structures in the semantic condition (assuming that being able to produce a verb is indicative of more consolidated knowledge of verb-event structure). Note that, if these assumptions are correct, one would also expect the association with verb production to be smaller in the lexical condition; however, we could not run the same analysis for the lexical condition because the vast majority of verbs in this condition were reported by parents as being produced by (almost) all children in our sample.

## Conclusion

Although theories of word learning predict that young children do not map word forms to multiple meanings (e.g., Markman, 1989; Trueswell et al., 2013; Yu & Smith, 2007), recent evidence indicates that child-directed speech is rich in word sense ambiguity, and the same is true for children's early vocabularies (Meylan et al., 2021).

The present study examined the effect of bottom-up lexical and top-down verb-event structure cues in early lexical ambiguity resolution. Given the ubiquitous role of lexical statistics in language development (Ambridge et al., 2015), we showed the importance of leveraging naturalistic conversations to disentangle the effect of different factors in sentence context. We found that children might be able to integrate both bottom-up verb lexical and top-down verb-event structure cues in sentence parsing to disambiguate the meaning of ambiguous words, supporting the idea that their word representations are contextual, and rich in surface and structural aspects from early in development (Srinivasan & Rabagliati, 2021).

[1] In all additional analyses, we also obtained the same results when using content words, pronouns and prepositions (Rabagliati et al., 2013), or only content words to compute prior associations.

## References


Alishahi, A., & Stevenson, S. (2007). A Cognitive Model for the Representation and Acquisition of Verb Selectional Preferences. *Proceedings of the Workshop on Cognitive Aspects of Computational Language Acquisition*, 41–48.

Ambridge, B., Kidd, E., Rowland, C. F., & Theakston, A. L. (2015). The ubiquity of frequency effects in first language acquisition. *Journal of Child Language*, *42*(2), 239–273.

Andreu, L., Sanz-Torrent, M., & Trueswell, J. C. (2013). Anticipatory sentence processing in children with specific language impairment: Evidence from eye movements during listening. *Applied Psycholinguistics*, *34*(1), 5–44.

Cabiddu, F., Bott, L., Jones, G., & Gambi, C. (2022). ChiSense-12: A sense-annotated corpus of child-directed speech. *Proceedings of The 13th Language Resources and Evaluation Conference*. Marseille, France. European Language Resources Association.

Connell, L., & Keane, M. T. (2004). What Plausibly Affects Plausibility? Concept Coherence and Distributional Word Coherence as Factors Influencing Plausibility Judgments. *Memory & Cognition*, *32*(2), 185–197.

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of child language*, *44*(3), 677-694.

Hahn, N., Snedeker, J., & Rabagliati, H. (2015). Rapid Linguistic Ambiguity Resolution in Young Children with Autism Spectrum Disorder: Eye Tracking Evidence for the Limits of Weak Central Coherence. *Autism Research*, *8*(6), 717–726.

Khanna, M. M., & Boland, J. E. (2010). Children's use of language context in lexical ambiguity resolution. Quarterly *Journal of Experimental Psychology*, *63*(1), 160–193.

Kidd, E., & Bavin, E. L. (2005). Lexical and referential cues to sentence interpretation: An investigation of children's interpretations of ambiguous sentences. *Journal of Child Language*, *32*(4), 855–876.

MacWhinney, B. (2000). *The CHILDES Project: Tools for analyzing talk. Transcription format and programs* (Vol. 1). Psychology Press.

Mani, N., Daum, M. M., & Huettig, F. (2016). "Proactive" in many ways: Developmental evidence for a dynamic pluralistic approach to prediction. *Quarterly Journal of Experimental Psychology*, *69*(11), 2189–2201.

Markman, E. M. (1989). *Categorization and naming in children: Problems of induction.* MIT Press.

Meylan, S., Mankewitz, J., Floyd, S., Rabagliati, H., & Srinivasan, M. (2021). *Quantifying Lexical Ambiguity in Speech To and From English-Learning Children*. PsyArXiv. https://doi.org/10.31234/osf.io/zxkm2

Rabagliati, H., Pylkkanen, L., & Marcus, G. F. (2013). Top-down influence in young children's linguistic ambiguity resolution. *Developmental Psychology*, *49*(6), 1076–1089.

Snedeker, J., & Trueswell, J. C. (2004). The developing constraints on parsing decisions: The role of lexical-biases and referential scenes in child and adult sentence processing. *Cognitive Psychology*, *49*(3), 238–299.

Snedeker, J., & Yuan, S. (2008). Effects of prosodic and lexical constraints on parsing in young children (and adults). *Journal of Memory and Language, 58,* 574–608.

Srinivasan, M., & Rabagliati, H. (2021). The Implications of Polysemy for Theories of Word Learning. *Child Development Perspectives*, *15*(3), 148–153.

Trueswell, J. C., & Gleitman, L. R. (2007). Learning to parse and its implications for language acquisition. In M. G. Gaskell (Ed.), *Oxford handbook of psycholinguistics*. Oxford, United Kingdom: Oxford University Press.

Trueswell, J. C., Medina, T. N., Hafri, A., & Gleitman, L. R. (2013). Propose but verify: Fast mapping meets cross-situational word learning. *Cognitive Psychology, 66,* 126–156.

Yacovone, A., Shafto, C. L., Worek, A., & Snedeker, J. (2021). Word vs. World Knowledge: A developmental shift from bottom-up lexical cues to top-down plausibility. *Cognitive Psychology*, *131*, 101442.

Yu, C., & Smith, L. B. (2007). Rapid word learning under uncertainty via cross-situational statistics. *Psychological Science, 18,* 414–420.


## Acknowledgments


The research reported in this article was supported by a Cardiff University School of Psychology PhD Studentship, and a British Academy Small Grant SRG1920\100600.

We would like to thank Kelsey Frewin for her help with the creation of the stimuli for the experimental task, and Holly Martin and Jennifer Lloyd for their help with child data collection.


## Appendix

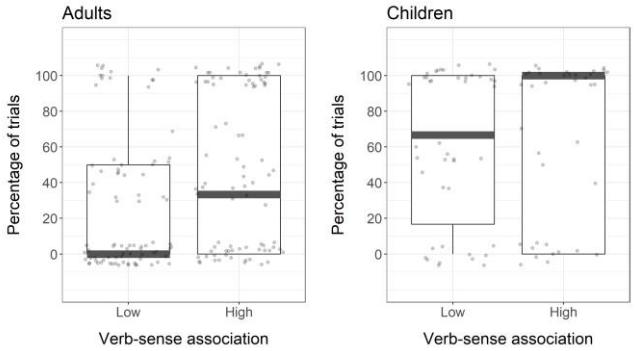


Figure A1

Boxplots showing the distribution of percentages of dominant sense choice in the lexical condition for adults and children, by verb-sense association. Median split was applied to verb-sense association only for graphical purposes, but the variable was kept continuous in the statistical model. Data points were jittered to avoid visual overlapping.

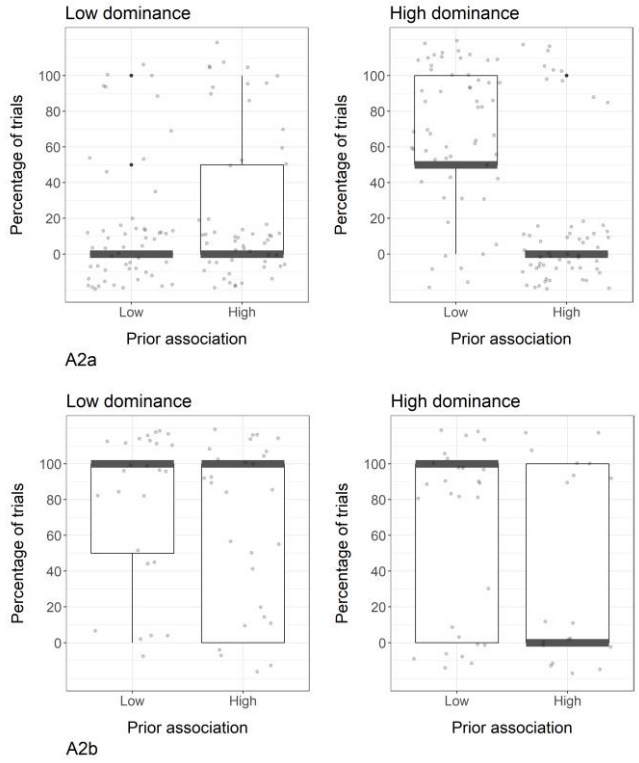


Figure A2
Boxplots showing the distribution of percentages of dominant sense choice in the lexical condition for adults (A2a) and children (A2b), as a function of prior association and sense dominance. Median split was applied to prior association and dominance only for graphical purposes, but these variables were kept continuous in the statistical model. Data points were jittered to avoid visual overlapping.

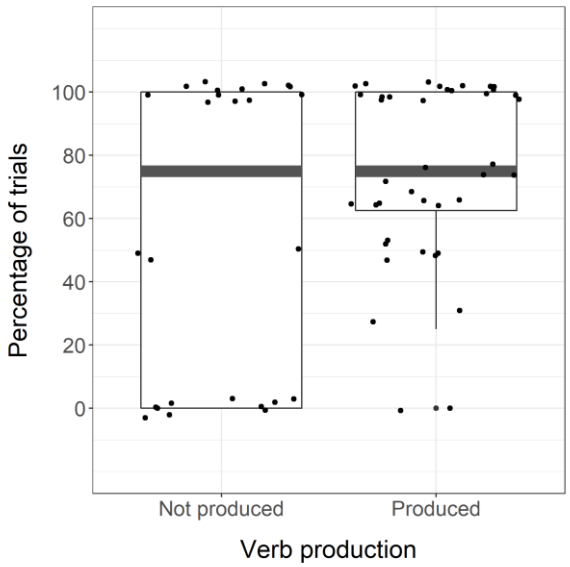


Figure A3
Boxplots showing the distribution of percentages of dominant sense choice in the semantic condition for children, by parent-report child verb production. Data points were jittered to avoid visual overlapping.

Table A1

Stimuli divided by 3 counterbalancing blocks. Each story has a prior context and a following control, lexical or semantic context. Verb-sense associations for subordinate and dominant senses are reported. These were computed as the raw frequency of verb-sense occurrence weighted by the number of times a sense appeared in ChiSense-12 as a verb object.

| **Block A** | | |
|---|---|---|
| ***Prior context*** | ***Control context*** | ***Verb-sense association (subordinate/dominant)*** |
| Sophia listened to some music | Then, she played in a band | .029 / .000 |
| John threw the ball | Then, Mary swung the bat | .078 / .000 |
| Wendy bought some tools and a piece of wood | Then, she got a nail | .056 / .014 |
| George had an apple for breakfast | Then, he ate a mousse | .077 / .000 |
| ***Prior context*** | ***Lexical context*** | |
| The teacher said goodbye to the daughter | Then, she looked at the sun | .000 / .041 |
| Harry got eggs, milk and sugar | Then, he held the flower | .000 / .006 |
| Olivia had some chips | Then, she saw the chicken | .005 / 053 |
| Jack got some arrows | Then, he made a bow | .000 / .054 |
| ***Prior context*** | ***Semantic context*** | |
| Julia and Beth wanted some milk | Then, Julia folded the glasses | .000 / .000 |
| Leo and Mark were waiting for the bus | Then, Mark rubbed out the line | .000 / .000 |
| John was putting on a shirt | Then, he rang the button | .000 / .000 |
| Charlie got some stamps this morning | Then, he sang the letters | .000 / .000 |
| **Block B** | | |
| ***Prior context*** | ***Control context*** | ***Verb-sense association (subordinate/dominant)*** |
| The teacher said goodbye to the daughter | Then, she talked to the son | .023 / .000 |
| Harry got eggs, milk and sugar | Then, he mixed the flour | .015 / .000 |
| Olivia had some chips | Then, she ate the chicken | .116 / .007 |
| Jack got some arrows | Then, he shot a bow | .111 / .000 |
| ***Prior context*** | ***Lexical context*** | |
| Julia and Beth wanted some milk | Then, Julia found the glasses | .007 / .016 |
| Leo and Mark were waiting for the bus | Then, Mark followed the line | .005 / .055 |
| John was putting on a shirt | Then, he touched the button | .000 / .014 |
| Charlie got some stamps this morning | Then, he looked for the letters | .004 / .011 |
| ***Prior context*** | ***Semantic context*** | |
| Sophia listened to some music | Then, she twisted a band | .000 / .000 |
| John threw the ball | Then, Mary got bitten by the bat | .000 / .000 |
| Wendy bought some tools and a piece of wood | Then, she chewed on a nail | .000 / .000 |
| George had an apple for breakfast | Then, he met a moose | .000 / .000 |
| **Block C** | | |
| ***Prior context*** | ***Control context*** | ***Verb-sense association (subordinate/dominant)*** |
| Julia and Beth wanted some milk | Then, Julia filled the glasses | .007 / .000 |
| Leo and Mark were waiting for the bus | Then, Mark stood in the line | .044 / .000 |
| John was putting on a shirt | Then, he undid the button | .071 / .000 |
| Charlie got some stamps this morning | Then, he posted the letters | .185 / .000 |
| ***Prior context*** | ***Lexical context*** | |
| Sophia listened to some music | Then, she got a band | .000 / .065 |
| John threw the ball | Then, Mary liked the bat | .000 / .033 |
| Wendy bought some tools and a piece of wood | Then, she drew a nail | .000 / .014 |
| George had an apple for breakfast | Then, he saw a moose | .038 / .085 |
| ***Prior context*** | ***Semantic context*** | |
| The teacher said goodbye to the daughter | Then, she relaxed under the sun | .000 / .000 |
| Harry got eggs, milk and sugar | Then, he trimmed the flower | .000 / .000 |
| Olivia had some chips | Then, she rescued the chicken | .000 / .001 |
| Jack got some arrows | Then, he ironed a bow | .000 / .000 |