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Let's See a Boy and a Balloon: Argument Labels and Syntactic Frame in Verb Learning

Sudha Arunachalam

Boston University

Sandra R. Waxman

Northwestern University

Correspondence should be sent to Sudha Arunachalam, Department of Speech, Language, and Hearing Sciences, Boston University, Boston, MA 02215. E-mail: sarunach@bu.edu

Abstract: It is by now well established that toddlers use the linguistic context in which a new word—and particularly a new verb—appears to discover aspects of its meaning. But what aspects of the linguistic context are most useful? To begin to investigate this, we ask how 2-year-olds use two sources of linguistic information that are known to be useful to older children and adults in verb guessing tasks: syntactic frame, and the semantic content available in the noun phrases labeling the verb's arguments. We manipulate the linguistic contexts in which we present novel verbs to see how they use these two sources of information, both separately and in combination, to acquire the verb's meaning. Our results reveal that like older children and adults, toddlers make use of both syntactic frame and semantically contentful argument labels to acquire verb meaning. But toddlers also require these two sources of information to be packaged in a particular way, into a single sentence that identifies 'who did what to whom.'

Acquiring a new word requires the learner to attend to and coordinate multiple sources of information to glean the word's meaning and grammatical properties (e.g., visual observation of

the world, the speaker's goals and intentions, the word's syntactic and discourse context). For verb acquisition in particular, linguistic information plays an important role. By two years of age, toddlers can exploit multiple components of a novel verb's linguistic context to acquire its meaning, such as its syntactic frame (e.g., Fisher, 1996, 2002; Hirsh-Pasek, Golinkoff, & Naigles, 1996; Naigles, 1990) and the semantic content of the noun phrases (or DPs) occupying its argument positions (e.g., Arunachalam & Waxman, 2011; Fisher et al., 1994).

The goal of the current investigation is to identify what kinds of linguistic information are most advantageous for toddlers' acquisition of verb meaning. We take as our starting point evidence that for older children and adults, too, both the syntactic frame in which the verb appears and the semantic content of its accompanying noun phrases support identification of an unknown verb's referent (Gillette, Gleitman, Gleitman, & Lederer, 1999; Piccin & Waxman, 2007; Snedeker & Gleitman, 2004). For example, adults are better able to guess the identity of a masked verb when they are given either that verb's syntactic frame or a list of the nouns with which it co-occurs (Gillette et al., 1999; Snedeker & Gleitman, 2004). Moreover, these factors contribute independently as well as in combination: the syntactic frame provides information about the type and number of arguments a verb takes and the noun phrases provide information about the kinds of entities that can be involved in the event, but the two sources together provide information about the selectional restrictions of the verb, allowing even better identification of the verb's referent (Gillette et al., 1999; Snedeker & Gleitman, 2004).

Here, we hypothesize that, like adults, toddlers will be most successful in a verb learning task when provided with both syntactic frames and rich semantic content in the accompanying noun

phrases. The proposal is not that a toddler's task in verb learning is identical to that of an adult. On the contrary, unlike adults, who already know hundreds of verb meanings, toddlers encountering a new verb for the first time face the additional task of determining how it maps to the world, and determining what kinds of things adults are likely to label in any given situation and in any given utterance. Also, because toddlers process language more slowly than adults (e.g., Fernald et al., 1998), it may be challenging for them to coordinate their linguistic and cognitive capacities swiftly and effectively enough to use linguistic information as adults do. Still, there is reason to suspect that toddlers do indeed benefit from informative linguistic contexts when learning new verbs. For example, 2-year-olds successfully learned the meanings of novel transitive verbs when they were presented in full noun phrase contexts (e.g., The boy is *pilking* a balloon) (Arunachalam & Waxman, 2011; Waxman, Lidz, Lavin, & Braun, 2009), but not when they were presented in pronoun contexts (e.g., He's *pilking* it) (Arunachalam & Waxman, 2011). This leads to the proposal under investigation here: that toddlers, like adults, will benefit from both syntactic and semantic information in combination.

To investigate this, we adapted Arunachalam and Waxman's (2011) novel verb learning task to focus more closely on how toddlers use linguistic information—both syntactic frame and semantically rich noun phrases, separately and in combination—to acquire a novel verb's meaning. As in previous work, we first present a novel verb (e.g., *pilking*) in the context of a visual scene, such as a boy waving a balloon, and then at test, we ask toddlers to point to "pilking" given two alternative scenes: one scene depicting a boy *tapping* a balloon, and the other depicting a boy waving a *rake.* Toddlers' responses reveal whether they have mapped the novel verb to *waving* and can extend it to a new situation involving a new object. But in the

current task, we go further, systematically uncoupling the syntactic and semantic information available in the sentences in order to identify the contribution of each source of linguistic information, specifically whether each is necessary and/or sufficient for successful learning. We present the same visual stimuli and the same test scenes in all conditions, but we manipulate the amount of semantic and syntactic information provided. In Experiment 1, we manipulate syntactic context, holding semantic information constant, and in Experiment 2, we manipulate the richness of the accompanying noun phrases, holding syntactic frame constant.

We adapted Arunachalam and Waxman's (2011) paradigm in another way: we significantly reduced toddlers' exposure to the novel verb and the visual scenes prior to the test phase. Arunachalam and Waxman presented the novel verb in several phases, including a linguistic familiarization phase in which toddlers heard the novel verb in conversation, four familiarization scenes (e.g., a man waving four different balloons), and a contrastive example of something that was "not *pilking*." In contrast, verb learning studies with older children (3 to 5 years of age) have provided significantly fewer exposures to the novel verb and scenes (e.g., Imai et al., 2005; Imai et al., 2008). In these studies children failed to acquire novel verbs from minimal exposure, though they successfully acquired novel nouns. Therefore, in the current study we minimize toddlers' exposure to the novel verbs and scenes to more closely align with the amount of exposure provided with Imai and colleagues' studies. This permits us to ask whether children's failure in Imai and colleagues' studies, in contrast to the successful verb learning in Arunachalam and Waxman (2011), can be accounted for by the amount of exposure alone. We focus on toddlers aged 2;3, who have demonstrated abilities to learn from minimal input (e.g.,

Arunachalam & Waxman, 2010; Arunachalam, 2013; Syrett, Arunachalam, & Waxman, 2013; Yuan & Fisher, 2009).

Experiment 1: Manipulating Syntax

We first focused on the contribution of syntactic frame, providing all toddlers with semantically rich noun phrases labeling the verb's arguments, but manipulating whether the syntactic context was informative. In the Sparse Syntax condition, toddlers heard the novel verb introduced as follows: "Let's see a boy, and a balloon. Let's see pilking!" Although the event participants were named with full noun phrases that specified their referents precisely, the syntactic context in which the novel verb appeared provided no information as to its argument structure.[1] In the Rich Syntax condition, in contrast, the full noun phrases were embedded in a transitive sentence that clearly specified the verb's argument structure: "A boy is gonna pilk a balloon. Let's see!"

The visual stimuli and procedure were similar to Arunachalam and Waxman (2011), except that the amount of exposure was severely stripped back: Toddlers heard the novel verbs just twice during familiarization (only once in a syntactically informative context) and saw only a single instance of the event described by the verb, presented twice on either side of the screen. Also

[1] Note that Sparse Syntax means that the syntactic frame in which the verb is embedded is relatively uninformative. This frame does still convey some information, e.g., that the novel word is a verb, can describe an ongoing event, etc.

unlike our prior work, we eliminated the preliminary dialogue phase (in which the novel verbs had been mentioned) as well as the contrastive exemplars. See Table 1.

Methods

Participants. Thirty-six typically-developing toddlers (18 males) with a mean age of 2;3 (range: 2;1-2;5) were included in the final sample. Toddlers were recruited from Evanston, IL and surrounding communities and were acquiring English as their native language with less than 25% exposure to another language. Caretakers completed the MacArthur-Bates Communicative Development Inventory: Words and Sentences (Fenson et al., 1993). Mean production vocabulary was 506 in the Sparse Syntax condition and 507 in the Rich Syntax condition (Sparse Syntax range: 140 to 679; Rich Syntax: 206 to 663); there were no differences in vocabulary between conditions.

To ensure that toddlers included in our final sample were capable of providing systematic pointing responses, they first participated in two training trials (see below). To be included in the final sample, toddlers had to execute a clear and correct pointing response on at least one of these two training trials, and to point clearly on at least one test trial. Eleven toddlers failed to meet these criteria and were replaced in the design. Two additional toddlers were excluded due to fussiness. This attrition rate is comparable to other work using a pointing task with this age group (e.g., Arunachalam & Waxman, 2010; Fernandes et al., 2006).

Materials

Visual stimuli. Adapted from Waxman et al. (2009). Toddlers viewed videos of human actors performing continuous actions on inanimate objects. These were edited to create the sequences described in Table 1 and were presented on a 20 in. screen.

Auditory stimuli. A female native speaker of American English produced the speech stimuli (described in Table 1) using child-directed speech. Speech was recorded in a sound-attenuated booth, synchronized with the visual stimuli, and presented on a speaker centered below the visual display.

Apparatus and Procedure. The toddler played with toys while the caregiver signed a consent form and completed the MacArthur checklist. The toddler and caregiver were then brought into an adjoining room where the toddler was seated in an infant booster seat, 16 inches from the television screen. The caregiver sat in the room and was requested not to talk during the session. One experimenter controlled the experimental procedure from behind a curtain; another sat next to the toddler to elicit responses. We asked toddlers to indicate their choice of scenes by pointing, and recorded their points with a video camera centered above the screen.

Toddlers first participated in a warm-up game designed to encourage them to point to the screen. Two video clips of Sesame Street characters were presented on the screen, side-by-side, and the experimenter asked the toddler to point, once to a familiar character (e.g., Elmo), and once to a familiar action (e.g., dancing). If a toddler was reluctant to point or pointed incorrectly, the experimenter demonstrated the correct response.

Next, each toddler participated in six verb learning trials, each featuring a different novel verb. Each trial comprised three phases: Linguistic Familiarization, Event Familiarization, and Test. Toddlers were randomly assigned to either the Sparse Syntax or Rich Syntax condition. In both conditions they saw exactly the same video scenes, but heard different auditory stimuli. See Table 1 for a representative trial, and Appendix A for a complete list of the novel verbs and actions. The six trials were presented in one of two random orders, balanced across conditions. The left-right positions of the two types of test scene were also counterbalanced.

Linguistic Familiarization phase (5 sec). First, toddlers viewed a still image taken from the first frame of the dynamic action scene (e.g., a boy waving a balloon). The auditory stimuli varied by condition (see Table 1). From this point on, toddlers in both conditions heard and saw the exact same stimuli.

Event Familiarization phase (12 sec). Next, toddlers viewed the dynamic action scene. First, the scene appeared on one side of the screen, and toddlers heard "Look, *pilking*!" After 6 sec the scene was presented on the other side of the screen, and they simply heard "Wow!" This second presentation was designed to show toddlers that scenes might appear on the left or right sides of the screen.

Test phase (14 sec). Finally, two new scenes appeared simultaneously, one on either side of the screen. One depicted the now-familiar action with a new object (e.g., waving a rake), and the other depicted the familiar object, but a new action performed on it (e.g., tapping the balloon). First, the scenes appeared for 6 sec, and toddlers heard, "Now look. They're different!" This phase was designed to give toddlers time to inspect both scenes, as both were novel to them. The

screen then went black (2 sec), and they heard, "Do you see *pilking*?" The scenes immediately re-appeared in their original locations for 6 sec, with the audio, "Find *pilking*!" Toddlers' pointing responses were recorded. No feedback was provided (e.g., "Now let's see another.").

Coding

Two condition-blind coders reviewed the videos of toddlers' points and recorded them as "Left," "Right," or "No Response." Coders agreed on 100% of trials. "No Response" trials were distributed evenly across conditions; in the Sparse Syntax condition, 8 toddlers failed to respond on one or two trials, and in the Rich Syntax condition, 6 toddlers failed to respond on one, two, or three trials. On the rare occasion in which a toddler pointed to both scenes in succession (this occurred on only 6 of the possible 216 trials), we used their first point as the dependent measure.

We calculated, for each toddler, the number of trials on which he or she pointed to the Familiar Action scene (e.g., waving a rake), and divided this by the total number of trials on which he or she pointed.

Predictions

If semantically informative noun phrases that label the event participants are sufficient to focus toddlers' attention on the appropriate part of the scene that is being labeled by the novel verb, they should successfully map the novel verbs in both the Rich and Sparse Syntax conditions. But if in addition to these semantically informative noun phrases, toddlers also require an informative syntactic context, then they should only succeed in the Rich Syntax condition, and in the Sparse

Syntax condition, they should perform no differently from chance (because there are two test scenes we define chance as a 0.50 proportion of points to the Familiar Action scene).[2]

Results

The results are depicted in Figure 1. As predicted, toddlers in the Rich Syntax condition preferred the Familiar Action scene (M = .65; *SD* = .26). We fit the data in the Rich Syntax condition to a multilevel model using maximum likelihood estimation with subject and trial as random effects, and with performance coded as 0.5 for points to the (correct) Familiar Action scene and −0.5 for points to the Familiar Object scene. The intercept parameter estimate for this model, 0.13, is significantly different from 0 on a normal distribution ($p < 0.02$), indicating that toddlers reliably preferred the Familiar Action scene (compared to chance) in this condition. This finding was bolstered by an analysis of individual trials: In the Rich Syntax condition, the number of individual trials on which toddlers pointed to the Familiar Action scene was significantly greater than the number expected by chance, ($\chi^2(1, N = 95) = 6.58, p < .02$).

[2] To provide assurance that chance performance is an appropriate baseline for this task, we tested a different 9 toddlers in a No Word condition, in which the visual stimuli were identical to Experiments 1 and 2, but no novel words were introduced. At test, toddlers were asked, "Which one do you like?" Seven toddlers performed at chance (0.50), one chose the Familiar Action scene on 2 of the 6 trials, and the other chose it on 4 of the 6 trials. These results support our use of 0.50 as chance performance.

Toddlers in the Sparse Syntax condition chose the Familiar Action scene about half the time (M = .49; *SD* =0.14). The intercept parameter estimate for this model of −0.002 is not significantly different from chance (p = 0.98).

Additionally, to explore whether performance in the two conditions differs from each other, we included data from both conditions in a model with subject and trial as random effects, and syntactic condition (Rich vs. Sparse) as a fixed effect; the parameter estimate for syntactic condition indicates that toddlers in the Rich Syntax condition were more likely to choose the Familiar Action scene than those in the Sparse Syntax condition, though this effect is marginally significant on a normal distribution (p = 0.056). Parameter estimates for all three models are in Table 2.

Discussion

These results offer two contributions. First, they demonstrate that by the age of 2;3, toddlers can successfully map novel verbs to actions and extend them to scenes involving a new participant object, even when provided with fewer observational and linguistic exposures than in previous paradigms (Arunachalam & Waxman, 2011; Waxman et al., 2009).

Second, these results reveal the key role of syntactic information in identifying the meaning of a novel verb. When provided with both semantically rich noun phrases labeling the verb's arguments and an informative syntactic context, toddlers successfully mapped the novel verbs to the action. In contrast, when provided with the same noun phrases, but uninformative syntax, toddlers failed to learn the verbs.

Toddlers' failure in the Sparse Syntax condition reveals that to learn the meaning of a novel verb, toddlers require more than the names of the event participants. We interpret this, coupled with their success in the Rich Syntax condition, as evidence that to learn verb meanings, toddlers depend upon syntactically informative frames that reveal the verb's argument structure (e.g., that it takes a subject and object).

In Experiment 2, we turn our attention to the contribution of semantics. We ask whether toddlers also require semantically informative noun phrases to acquire verb meanings, or whether syntactically informative frames are sufficient. We also pursue an alternative explanation of toddlers' failure in the Sparse Syntax condition: perhaps these toddlers failed to recognize that the novel word was a verb. Although the novel word appeared with verbal morphology ("pilking"), this may not have been sufficient for these young learners to determine the word's grammatical category. In Experiment 2, therefore, we present novel verbs in syntactically informative frames that will allow toddlers to determine their grammatical category.

Experiment 2: Manipulating Semantics

Our goals in Experiment 2 are twofold. First, we pursue our investigation of the information toddlers require to successfully acquire a novel verb by holding syntactic information constant—both conditions provide a syntactically informative frame—and manipulating the richness of the semantic information. Second, this design also permits us to pursue the possibility that the syntactic information provided in the Sparse Syntax condition of Experiment 1 was not sufficient to permit toddlers to identify the novel word as a verb.

To address these goals, we introduced toddlers to novel verbs embedded in transitive sentences, using pronouns to label the arguments (e.g., "He's pilking it"). We selected pronoun contexts because they provide syntactic information about the verb's argument structure without providing specific semantic information about the referents of those arguments. This allows us to keep constant the amount of syntactic information we provide. Further, toddlers successfully use pronoun contexts to determine a novel word's grammatical category (e.g., Mintz, 2006), which ensures that if toddlers fail to acquire novel verbs in Experiment 2, it will not be because they failed to realize the novel word was a verb.

What varied across conditions was the richness of the semantic information provided. In the Sparse Semantics condition, toddlers received nothing more than the semantic information available in the pronouns that labeled the verb arguments, that is, information about animacy and gender. They heard, "Let's see what happens now. He's gonna pilk it." In the Rich Semantics condition, toddlers were provided with semantically rich noun phrases labeling the verb's arguments: "Let's see a boy and a balloon. He's gonna pilk it." Notice that in the Rich Semantics condition, as in the Rich Syntax condition (Experiment 1), toddlers receive both rich semantic information and informative syntax, but in Experiment 2's Rich Semantics condition, we provide the two pieces of information in different sentences. To use both pieces of information, toddlers must integrate the noun phrases from the first sentence with the pronoun contexts in the second, which will require them to use their pronoun resolution abilities, a skill that toddlers are still developing (e.g., Hartshorne, Nappa, & Snedeker, 2010; Pyykkönen, Matthew, & Järvikivi, 2010; Song & Fisher, 2005).

Methods

These were identical to Experiment 1, except for the auditory information presented in the Linguistic Familiarization phase. See Table 3.

Participants. Toddlers were recruited from same population as Experiment 1. Thirty-six toddlers were included for analysis (18 males), mean age 27.0 (range 25.0 to 29.6). Vocabulary scores did not differ significantly between conditions (Sparse Semantics mean 495, range 115 to 673; Rich Semantics mean 502, range 211 to 682), or between experiments. We used the same inclusion criteria as in Experiment 1. Thirteen toddlers were excluded for failure to point clearly and/or correctly during training.

Coding

As in Experiment 1, toddlers' points were coded from the videos of the sessions. Coders agreed on 100% of trials. Four toddlers in the Rich Semantics condition failed to point on one, two, or three trials, and one toddler failed to point on five trials; in the Sparse Semantics condition, three toddlers failed to point on one or three trials. In addition, on three trials, the point was directed either to both scenes simultaneously, or to the center of the screen, between the two test scenes. We excluded these three trials from analysis. On the one trial (out of the possible 216) on which a toddler pointed to both scenes in succession, we took their first point. As in Experiment 1, we calculated the number of trials on which each toddler pointed to the Familiar Action scene (e.g., waving a rake), and divided this by the total number of trials on which that toddler pointed.

Predictions

If an informative syntactic context, even with semantically bleached arguments, is sufficient to promote verb learning, then toddlers should succeed in both the Sparse and Rich Semantics conditions (but see Arunachalam & Waxman, 2011, in which slightly younger toddlers failed with semantically bleached arguments). If an informative syntactic context is insufficient, and toddlers also require access to semantically rich noun phrases that allow them to identify the verb's arguments, then they should struggle in the Sparse Semantics condition. If having access to both syntactic and semantic information is sufficient, then they should succeed in the Rich Semantics condition. But if they require that information to be packaged in a single sentence—without need for pronoun resolution—for them to process it effectively, they may have difficulty in the Rich Semantics condition as well.

Results

The results, depicted in Figure 2, are straightforward: toddlers failed to map novel verbs to the Familiar Action scene in either condition (Rich Semantics: M = 0.50, SD = 0.28; Sparse Semantics: M =0.43, SD = 0.26). We fit the data to multilevel models using maximum likelihood estimation as in Experiment 1. In the Rich Semantics condition, a model with subject and trial as random effects, and performance coded as 0.5 for points to the Familiar Action and −0.5 for points to the Familiar Object scene, yielded an intercept parameter estimate of 0.032, not significantly different from 0 (p = 0.58). In the Sparse Semantics condition, a model with the same factors yielded an intercept parameter estimate of −0.060 (p = 0.35).

To look at differences between conditions, we again included data from both conditions in a model with subject and trial as random effects, and semantic condition (Rich vs. Sparse) as a fixed effect. The parameter estimate for semantic condition is 0.090, with a *t*-value of 1.11, which is not significant on a normal distribution ($p = 0.27$); performance thus did not significantly differ between conditions. Parameter estimates for all three models are in Table 4.

Discussion

These results shed light on the role of syntactic and semantic information in verb learning. In both conditions, we presented an informative syntactic context; toddlers' failure in the Sparse Semantics condition indicates that syntactic information alone is insufficient for successful verb learning. This finding that toddlers did not learn verb meanings in pronoun contexts, which replicates evidence from slightly younger toddlers (Arunachalam & Waxman, 2011), may be surprising, especially because there was only one salient animate and one salient inanimate entity in the visual scene, and because pronouns do offer information about the animacy of their referents. It should have been trivial to identify the referents of those pronouns in such a sparse scene. We suspect that toddlers in the Sparse Semantics condition, in the absence of full noun phrases labeling the event participants, may have entertained several possible interpretations for the meaning of the novel verb, such as "holding a stick-like object," in which case both of the test scenes would be possible referents (Arunachalam & Waxman, 2011). We propose that with development, as learners establish better initial hypotheses about what event a verb might describe, they are less likely to consider unusual interpretations even without the benefit of full noun phrase descriptions.

But toddlers' failure in the Rich Semantics condition, coupled with the results of Experiment 1, indicates that neither syntactic nor semantic information on their own were sufficient to support verb learning. This finding is even more surprising. Toddlers in the Rich Semantics condition of the current experiment were provided the same pieces of information as in the Rich Syntax condition in which toddlers *succeeded* in Experiment 1. The only difference is that in Experiment 1, these two pieces of information were presented in a single sentence. When the information was presented in separate sentences in the Rich Semantics condition in Experiment 2, and when toddlers therefore were required to integrate information across the two utterances, and to resolve the pronouns (*he, it*) to their antecedents in the previous sentence (*a boy, a balloon*), toddlers had difficulty. It could be that toddlers simply struggled to resolve the pronouns. It could also be that they had difficulty making use of the rich semantic information in the first sentence because it, was, essentially, too much information at the wrong time—instead of helpfully drawing their attention to the referents in their argument positions, the noun phrases drew attention to the event participants absent any syntactic information that could help them discover the event participants' role in the events. Perhaps integrating syntactic and semantic information across utterances is too challenging for these young toddlers, or perhaps they could successfully integrate them if they appeared in the opposite order—pronoun frame followed by rich noun phrases—which would allow them to process the syntactic information before turning their attention to the rich noun phrases and their interesting object referents.[3]

[3] Thanks to an anonymous reviewer for raising this last possibility.

Finally, these results are consistent with our suggestion that toddlers' difficulty in the Sparse Syntax condition of Experiment 1 did not stem from their failure to identify the novel word as a verb. After all, in Experiment 2, although verbs in both conditions were presented in informative syntactic contexts, contexts that permit toddlers to identify the word as a verb, toddlers still struggled to identify their meanings. This supports our proposal that information about syntactic frame, over and above grammatical category, is a critical support for verb learning.

General Discussion

In these two experiments, we examined the contributions of semantic and syntactic information in 2-year-olds' ability to acquire novel verb meanings. In Experiment 1, we held constant the semantic content of the novel verb's accompanying noun phrases and manipulated the syntactic frame in which the verb was embedded. In Experiment 2, we held constant the syntactic frame in which the novel verb was presented and manipulated the semantic content of the accompanying noun phrases. These results offer two main contributions: first, we demonstrate that toddlers can acquire novel verb meanings from very limited exposure, and second, we reveal the role of linguistic context in their success.

Although previous work demonstrated successful verb learning in toddlers aged 2;0 using a very similar task (Arunachalam & Waxman, 2011; Waxman, Lidz, Lavin, & Braun, 2009), in those studies toddlers received much richer linguistic exposure to novel verbs and observational exposure to referential scenes. The present study shows that at least by age 2;3, such rich exposure is not necessary, provided the linguistic contexts in which the novel verbs are presented are sufficiently informative (see also Syrett et al., 2013). The current design is very similar to

other verb learning studies in providing a small number of exposures, such as Imai et al. (2005; Imai et al., 2008). However, those studies found failures to learn and extend novel verbs at age 3 and beyond. Here, we demonstrate that even 2-year-olds can map and extend a novel verb when the linguistic context provides rich syntactic and semantic information. This brings the experimental findings closer in line with children's productive abilities; by age two, toddlers have acquired many verbs and continue to do so rapidly in their daily lives (e.g., Naigles, Hoff, & Vear, 2009).

Our second contribution is insight into what kinds of linguistic contexts were sufficiently informative for toddlers in this task. We found that they required both rich syntactic frame and rich semantic content in the surrounding words: While they successfully learned novel verbs presented in transitive frames with full noun phrase descriptions labeling the event participants (e.g., "A boy is gonna pilk a balloon"), they had difficulty when either the transitive frame or the full noun phrase descriptions were missing.

However, this rich information, though necessary, was not sufficient for successful learning. Only when the rich information was packaged in a single sentence did toddlers succeed. That is, they acquired the verbs when provided rich semantics and rich syntax in Experiment 1: "A boy is gonna pilk a balloon", but not when provided rich semantics and rich syntax in Experiment 2: "Let's see a boy and a balloon. He's gonna pilk it." Toddlers needed to know not only who and what were involved, but who did what to whom.

This result points to the importance of considering not only how much information is presented, but also how it is packaged. The two-sentence condition may, for example, have taxed toddlers'

working memory or pronoun resolution abilities, preventing them from making use of this information to settle on the verb's meaning. To succeed in the two-sentence condition, after all, they were required to resolve the pronouns in the second sentence ("He's gonna pilk it") with their full noun phrase antecedents in the first sentences ("Let's see a boy, and a balloon."). Studies of online sentence processing suggest that children are slower at pronoun resolution than adults (e.g., Hartshorne et al., 2010; Pyykkönen et al., 2010). If toddlers struggled to match up "the boy" as the subject of the verb and "the balloon" as its object, they could have determined that the novel word is a verb, and could have determined its argument structure, but would have lacked information about the selectional restrictions of the verb (Snedeker & Gleitman, 2004). Without knowing that "pilking" is something a boy can do to balloons, toddlers may have struggled to extend the novel verb to apply to new situations. We hypothesize that as toddlers' conceptual understanding (e.g., better initial hypotheses about what event a verb might describe) and linguistic abilities (e.g., more efficient sentence processing and anaphora resolution) develop, they become better at integrating syntactic and semantic information presented in different sentences.

In future work, it will be important to identify how the optimal linguistic context for any given learning situation varies as a function of the linguistic properties of the language being acquired. In languages that allow noun phrase arguments to be freely dropped, such that verbs often appear in isolation (e.g., Japanese, Korean), the full noun phrase sentences that we found particularly advantageous for English learners may in fact be problematic (Arunachalam et al., 2013; Imai et al., 2008). Toddlers acquiring Korean, for example, hear transitive sentences with both overt subject and overt object no more than about 35% of the time (Kim, 2000). Although

full noun phrases convey more information, the rarity of sentences with two full noun phrases in such a language may cancel out the benefit of informativeness. In other words, because Korean learners hear such rich sentences relatively rarely, they may struggle to use this information on-line in a word learning situation.

In fact, the evidence supports this hypothesis. In a similar task with Korean-acquiring toddlers aged 2;0, we found that Korean learners performed *better* in a sparse condition providing only a bare verb (e.g., Look, *pilking*!) than a rich condition providing syntactic frame and informative noun phrases (e.g., The man is *pilking* the balloon) (Arunachalam et al., 2013). (Importantly, however, they did not perform above chance levels in either condition, suggesting that although sparser contexts were easier for Korean learners to process and allowed them to avoid the pitfall of mapping the novel word to an object, these contexts nevertheless did not provide sufficient information for toddlers to be able to solve the word learning task and map the verb correctly, just as pronoun contexts are insufficient for English learners in the current study.) This suggests that a toddler's experience with her native language shapes her ability to extract information from the input she hears. One hypothesis for future research is whether, because discourse plays a hefty role in determining whether noun phrases are elided in Korean (Huang, 1984), Korean-acquiring toddlers would be better at integrating information across two different sentences in a discourse and would thus perform best in the two-sentence condition in which English learners struggled.

By two years of age, toddlers have remarkable abilities to glean a novel verb's meaning from a brief encounter. Considered in conjunction with other work, our results identify both continuity

and change across development. Like older children and adults, toddlers recruit both semantic and syntactic information from the sentence in which the novel verb appears. This indicates that the ability to identify and integrate semantic and syntactic streams of information, and to use them in the service of word learning, shows continuity over development. At the same time, however, we also see evidence for developmental change: unlike more experienced language users, toddlers struggled unless the rich syntactic and semantic information were packaged into a single sentence. This pattern suggests that what develops is the ability to make use of both of these kinds of information given the processing and attentional demands of the learning situation.

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APPENDIX A. Actions and objects for each trial.

Novel Word	Familiarization Scene	Test Scenes	
		Familiar Object	Familiar Action
dack	Boy pushing chair	Boy lifting chair	Boy pushing box
larp	Girl stroking stuffed dog	Girl kissing dog	Girl stroking frisbee
pilk	Boy waving balloon	Boy tapping balloon	Boy waving rake
wug	Girl twirling umbrella	Girl twisting umbrella	Girl twirling pillow
tope	Boy pulling bunny	Boy tossing bunny	Boy pulling drum
sem	Girl washing cup	Girl drinking from cup	Girl washing plate

TABLE 1. Experiment 1. One representative trial (of six) in each condition.

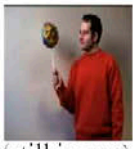
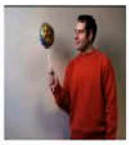
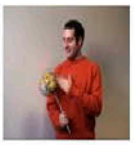
	LINGUISTIC FAMILIARIZATION	EVENT FAMILIARIZATION		TEST	
	 (still image)				
Experiment 1 **Manipulating Syntax**	<u>Sparse Syntax</u> Let's see a boy and a balloon. Let's see *pilking*!	Look, *pilking*!	Wow!	Now look, they're different! Where's *pilking*?	
	<u>Rich Syntax</u> A boy is gonna *pilk* a balloon! Let's see!				

TABLE 2. Experiment 1. Parameter estimates from multilevel models.

Comparison	Effect	Estimate	S.E.	*t*-value
Rich Syntax alone	Intercept	0.13	0.056	2.42*
Sparse Syntax alone	Intercept	−0.002	0.076	−0.027
Rich and Sparse Syntax	Intercept	−0.0039	0.057	−0.068
	Syntactic Condition (Rich vs. Sparse Syntax)	0.14	0.071	1.91†

* $p < 0.02$, † $p = 0.056$

TABLE 3. Experiment 2. Representative trial in each condition.

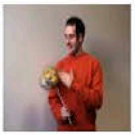
	LINGUISTIC FAMILIARIZATION	EVENT FAMILIARIZATION		TEST
	 (still image)			 
Experiment 2 **Manipulating Semantics**	Sparse Semantics: Let's see what happens now. He's gonna *pilk* it!	Look, *pilking*!	Wow!	Now look, they're different! Where's *pilking*?
	Rich Semantics: Let's see a boy and a balloon. He's gonna *pilk* it!			

TABLE 4. Experiment 2. Parameter estimates from multilevel models.

Comparison	Effect	Estimate	S.E.	*t*-value
Rich Semantics alone	Intercept	0.032	0.057	0.56
Sparse Semantics alone	Intercept	0.060	0.064	−0.93
Rich and Sparse Semantics	Intercept	−0.059	0.061	−0.96
	Semantic Condition (Rich vs. Sparse Semantics)	0.090	0.081	1.11

FIGURE 1. Experiment 1. Mean proportion of points to the Familiar Action scene, as a function of condition.

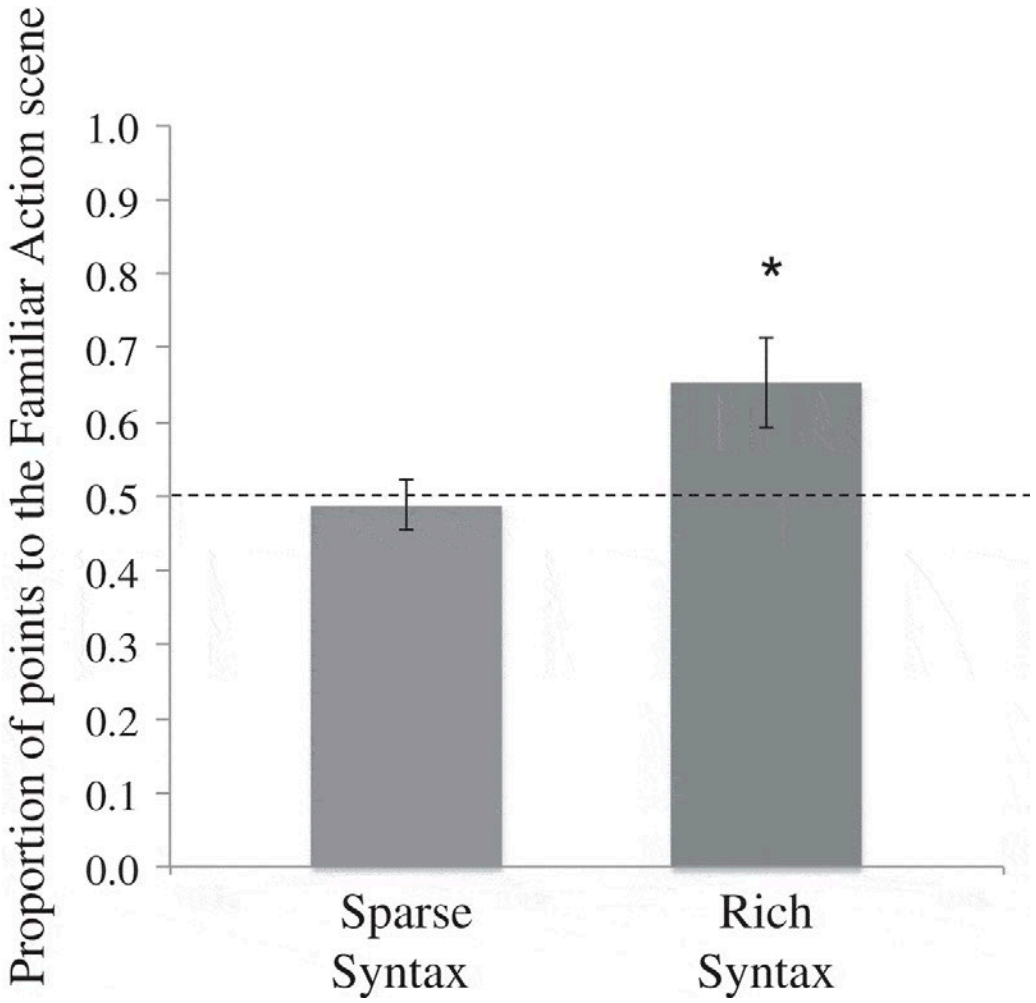


FIGURE 2. Experiment 2. Mean proportion of points to the Familiar Action scene, as a function of condition.