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To cite this article: Sudha Arunachalam , Emily Escovar , Melissa A. Hansen & Sandra R. Waxman (2013) Out of sight, but not out of mind: 21-month-olds use syntactic information to learn verbs even in the absence of a corresponding event, *Language and Cognitive Processes*, 28:4, 417-425, DOI: [10.1080/01690965.2011.641744](https://doi.org/10.1080/01690965.2011.641744)

To link to this article: <https://doi.org/10.1080/01690965.2011.641744>



Published online: 13 Mar 2012.



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Out of sight, but not out of mind: 21-month-olds use syntactic information to learn verbs even in the absence of a corresponding event

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By 27 months of age, toddlers hearing a novel verb in transitive syntax are able to (1) establish an initial representation for the verb based on its syntactic properties alone, even in the absence of a relevant visual scene, and (2) retrieve this representation later when a candidate causative referent comes into view. This ability is important considering that over 60% of the verbs that mothers produce in conversations with their children refer to events that are not currently observable. Here, we advance this finding in two ways. First, we demonstrate the same ability in 21-month-olds, who do not yet show mastery of transitive structures in their own productions. Second, we use analyses of toddlers' eye gaze to explore the time-course with which they process the novel verb and assign its referent when candidate scenes become available. These results (1) provide the first evidence that 21-month-olds establish a representation of a novel verb's meaning from syntax alone, and (2) establish that they process and assign meaning to novel verbs with a similar time-course to that for novel nouns. The findings are thus relevant to our understanding of both word learning and lexical processing of novel words.

Keywords: Word learning; Lexical processing.

In the natural course of a day, toddlers hear a great deal of conversation about objects and events that are nowhere to be seen (e.g., “Daddy’s outside painting the fence”). This is particularly true for verbs: More than 60% of the verbs that mothers produce in conversations with their children refer to absent events, that is, to events that are not currently observable (Tomasello & Kruger, 1992). Can toddlers learn verbs from such encounters? To do so, toddlers must establish an initial representation for the verb based on its linguistic context alone. But a single encounter with a new word can offer only a rough index of its meaning (Carey & Bartlett, 1978). If toddlers are to fill in

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We are grateful to Paul Bloom and an anonymous reviewer for helpful comments, and to Mihwa Kim for help with data collection and coding. A subset of these data was reported in the *Proceedings of the 35th Annual Boston University Conference on Language Development*. This research was supported by NIH-HD30410 (SRW).

more precise aspects of meaning, they must also be able to access their initial representation, however sparse it may be, and add to or refine it when they encounter that word later, an ability known as “cross-situational learning” (e.g., Blythe, Smith, & Smith, 2010; Gillette, Gleitman, Gleitman, & Lederer, 1999; Gleitman, 1990; Pinker, 1989; Siskind, 1996; Smith & Yu, 2008; Yu & Smith, 2007).

Are young word learners up to these challenges? Can they establish an initial representation of a novel verb’s meaning from its linguistic context—even absent a corresponding event—and then retrieve that representation on later encounters? The literature on verb learning suggests that they can. Two-year-olds are sensitive to correlations between a verb’s meaning and its syntactic properties (e.g., that in English, verbs occurring in *transitive* syntax often refer to *causative* events), and capitalise on these correlations to acquire meaning: If a novel verb occurs in transitive syntax, they expect it to refer to a causative event, but if it occurs in intransitive syntax, they do not (Arunachalam & Waxman, 2010; Hirsh-Pasek & Golinkoff, 1996; Naigles, 1990; Naigles & Kako, 1993; Noble, Rowland, & Pine, 2011; Yuan & Fisher, 2009).

Recent evidence reveals that even in the absence of any accompanying event, 2-year-olds hearing a novel verb in transitive syntax are able to (1) establish an initial representation for the verb based on its syntactic properties alone, and (2) retrieve this representation later when a candidate causative referent comes into view (Arunachalam & Waxman, 2010; Yuan & Fisher, 2009). In Arunachalam and Waxman, 27-month-olds first viewed scenes in which two actors were engaged in conversation, incorporating a novel verb (e.g., *fezzing*). The novel verb appeared in either transitive syntax (e.g., “The boy wants to *fez* the girl”) or intransitive syntax (e.g., “The boy and the girl want to *fez*”). Toddlers then viewed two dynamic scenes. In one, two actors were engaged in a causative action (e.g., boy spins girl in circles); in the other, the same two actors performed synchronous actions (e.g., boy and girl each wave one hand). Toddlers were asked to “find *fezzing*”. The results were clear: Toddlers who had heard conversations with transitive sentences chose the causative scene at test; those who had heard intransitive sentences did not. Strikingly, although most 27-month-olds have only recently begun to express familiar verbs consistently in syntactic constructions (e.g., Tomasello, 2003; Tomasello & Merriman, 1995), they were nonetheless able to use such constructions to establish an initial representation for a novel verb, even in the absence of a relevant visual scene, and then retrieve this representation later.

What remains to be seen, however, is whether these capacities are available to language learners even earlier. To address this issue, we focused on 21-month-olds: At this developmental juncture, although most toddlers produce some verbs, they do not yet embed them consistently in transitive or intransitive constructions (e.g., Tomasello, 2003; Tomasello & Merriman, 1995). At issue, then, is whether these toddlers can use syntactic information (e.g., transitivity) to establish initial representations of verb meaning, and whether these representations are sufficiently robust to be accessed later, when toddlers encounter the verbs again.

Some evidence exists on 21-month-olds’ abilities to use linguistic information to interpret novel verbs. First, Yuan, Messenger, and Fisher (2011) report that 21-month-olds hearing a novel verb in a sentence can count the *number of participants* mentioned in the sentence and match this to the number of actors they expect to see in the event (see also Brandone, Addy, Pulverman, Golinkoff, & Hirsh-Pasek, 2006). In addition, Gertner, Fisher and Eisengart (2006) document that 21-month-olds can use the *word order* of the sentence in which a novel verb appears as a cue to its meaning. For

example, toddlers who heard “The girl is gorping the boy” preferred a scene in which a girl acted on a boy to a scene in which a boy acted on a girl.

But whether toddlers can take advantage of syntactic information alone to establish a novel verb’s meaning remains an open question. For example, if the number of participants mentioned in the sentence and their relative order are held constant, can toddlers use the syntactic positions of the named participants (in a transitive or intransitive construction) to determine a novel verb’s meaning, absent a relevant referential scene?

To address this question, we adapted Arunachalam and Waxman’s (2010) task, designed for 27-month-olds, modifying it slightly to accommodate younger toddlers. Specifically, we measured toddlers’ looking behaviour rather than their pointing responses to the test query.

Looking time measures offer several distinct advantages over pointing in participants younger than 2 years of age. Not only is looking time more robust at this age (see Arunachalam & Waxman, 2011), it also allows us to determine *how quickly* toddlers fixate a particular scene once they hear the novel verb in the test query. Note that for cross-situational learning to be effective, it is essential that toddlers retrieve their representation of a novel word’s meaning rapidly and update it with new information as it becomes available. Interestingly, most research on how quickly children retrieve lexical representations and identify their referents has focused on *familiar* words (e.g., Fernald & Hurtado, 2006; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998; Lew-Williams & Fernald, 2007; Swingley, Pinto, & Fernald, 1999). Considerably less is known about novel word processing. Moreover, most of the research that has focused on novel words has primarily studied novel *nouns* and not novel *verbs* (Booth & Waxman, 2009; Halberda, 2006; Schafer, 2005; Thorpe & Fernald, 2006; Vouloumanos & Werker, 2009). This research on novel nouns suggests that toddlers may require significantly more time to retrieve representations for novel words than familiar ones (e.g., Booth & Waxman, 2009).

METHODS

Participants

Forty typically-developing toddlers (mean: 21.2 months; range: 19.0–23.9) were included in the final sample. All were recruited from Evanston, IL and surrounding communities, and were acquiring English as their native language, hearing other languages <25% of the time. Caretakers completed the MacArthur Long Form Vocabulary Checklist: Words and Sentences (Fenson et al., 1993). Toddlers’ production vocabulary ranged from 6 to 566 words; there were no significant differences in vocabulary between conditions. An additional nine toddlers were excluded from analysis due to fussiness, and nine due to failure to look at the screen for 50% or more of the time during the test phase on three or more test trials.

Materials

Our materials were identical to Arunachalam and Waxman (2010; see Figure 1). Toddlers in both conditions viewed precisely the same visual scenes throughout. What varied was the syntactic context in which novel verbs were presented within the Dialogue Phase only. To begin each trial, toddlers viewed digitised video recordings of two women engaged in a dialogue which incorporated a novel verb (e.g., *fezzing*).







	Dialogue Phase		Test Phase		
			Baseline (24 sec)	Response (24 sec)	
			 		 
Observational Stream					
Linguistic Stream	Transitive Condition A: Guess what? B: What? A: The lady <i>fezzed</i> my brother. B: Really? The lady <i>fezzed</i> your brother? A: And the boy is going <i>to fez</i> the girl. B: Oh yes. He is going <i>to fez</i> her.	Intransitive Condition A: Guess what? B: What? A: The lady and my brother <i>fezzed</i> . B: Really? The lady and your brother <i>fezzed</i> ? A: And the boy and the girl are going <i>to fez</i> . B: Oh yes. They are going <i>to fez</i> .	Look! Wow!	Where's <i>fezzing</i> ?	Do you see <i>fezzing</i> ?

Figure 1. Stimuli from one representative trial. Reprinted from *Cognition*, 114(3), S. Arunachalam & S. R. Waxman, Meaning from syntax: Evidence from 2-year-olds, pp. 442–446, Copyright 2010, with permission from Elsevier.

Toddlers in the Transitive condition heard the novel verb in a transitive sentence; those in the Intransitive condition heard the same content words, but in intransitive sentences. Because no candidate referents of the verb were available for inspection, if toddlers were to glean information about the verb’s meaning from these dialogues, they had to do so from the syntactic information alone. Next, two test scenes were presented simultaneously. Toddlers in both conditions heard, e.g., “Where’s *fezzing*?” Because no syntactic information was available at test, if toddlers were to identify the verb’s referent, they had to call upon their initial representation, established earlier in the Dialogue Phase.

Apparatus and procedure

Toddlers played freely with toys while the caregiver signed a consent form and completed the MacArthur Vocabulary Inventory. The toddler and caregiver were then invited into an adjoining room where the toddler was seated in an infant seat, 18 in from a 16 × 12 in television monitor. The caregiver sat behind the toddler and was requested not to talk or otherwise interact with the child during the session. The experimenter controlled the experimental procedure from behind a curtain. Toddlers’ looking behaviour was recorded with a video camera centred above the screen.

Toddlers participated in **six trials**, each featuring a different verb. Two training trials involving familiar verbs (*sleep* and *hug*) were followed by four experimental trials involving novel verbs (e.g., *fez*). Each trial incorporated two phases: Dialogue and Test. For experimental trials, toddlers were randomly assigned to either the Transitive or Intransitive condition. Toddlers in both conditions saw the same video scenes on all trials, but heard different auditory stimuli (Figure 1). The four experimental trials were presented in one of two random orders, balanced across conditions. The left-right positions of the two types of test scene were counterbalanced across trials.

Dialogue phase

Each trial began with a scene of two women conversing, using either a known verb (on the two training trials) or a novel verb (on the four experimental trials). One training trial involved the verb “sleep”, used intransitively, and the other involved the verb “hug”, used transitively. The experimental trials varied by condition. They

involved either transitive sentences, e.g., “Guess what? The boy fezzed his brother” (Transitive condition), or conjoined-subject intransitive sentences, e.g., “Guess what? The boy and his brother fezzed” (Intransitive condition). Each dialogue consisted of two six-sentence video clips, averaging 34 s, including eight mentions of the verb in different tenses and with different noun phrase arguments. Dialogue videos appeared in the centre of the screen.

Test phase

Toddlers then saw the two test scenes presented simultaneously, side-by-side. On training trials, the event type was held constant across test scenes: On the sleep trial, both test scenes depicted one participant (a woman sleeping, and the same woman crying). On the hug trial, both scenes depicted two participants (a woman hugging a toy, and the same woman lifting a box). On experimental trials, both test scenes depicted the same two participants (e.g., a man and a woman), with the event *type* differing in each test scene: (1) a synchronous event (e.g., man and woman each wave one hand in circles), and (2) a causative event (e.g., the man spins the woman). On all four experimental trials, each test scene depicted two moving participants. Each test scene was 5×4.5 in. They appeared on a black background with a 3 in horizontal space between them.

For both training and experimental trials, the test phase began with a 24 s inspection period, during which toddlers heard “Look! Wow!” and had an opportunity to inspect the test scenes, both of which were novel to them. The screen then went black for 1.5 s, during which time toddlers heard the test query involving the novel verb, e.g., “Where’s fezzing?” The test scenes then reappeared for 24 s, and toddlers heard: “Do you see fezzing? Find fezzing!” Toddlers’ eye gaze was recorded as they viewed the scenes. Because the novel verb appeared only in a neutral syntactic context during this test phase, any difference in eye gaze behaviour in the two conditions must be due to the syntactic information presented in the dialogues, before the candidate visual scenes appeared.

Coding

A trained coder, blind to condition assignment, coded the video recordings of toddlers’ eye gaze with the sound removed. The coder identified for each frame (30 frames per second) whether the eyes were oriented to the left scene, the right scene, or neither scene (including track loss). Trials on which “neither” looks comprised over 50% of the Test Phase were excluded from the analysis (8% of all trials). A second trained coder independently coded 20% of trials; agreement was 96% (Cohen’s kappa = 0.95).

Predictions

If 21-month-olds are able to use the syntactic information presented in the dialogues to determine the event type described by the novel verb, then toddlers in the Transitive condition should devote more visual attention to the causative test scene than toddlers in the Intransitive condition. Recent evidence on novel *noun* processing in a similar paradigm suggests that toddlers’ responses will not become evident until at least 2.5 s after the novel verb’s onset (Booth & Waxman, 2009).

RESULTS

We examined toddlers’ looks to the causative scene upon hearing the novel verb in the test query (e.g., “Where’s mooping?”). Proportions were calculated by dividing looks to causative scene by total coded looks (that is, including “neither” looks). Because we expected that toddlers would require at least 2.5 s to look to the verb’s referent (Booth & Waxman, 2009), we analysed looking behaviour in the first 5 s of the test period, dividing this window into two periods of 2.5 s each (Figure 2). In the first 2.5 s after the novel verb’s onset, performance in the two conditions did not differ (mean proportion of frames on which toddlers looked to the causative scene: Transitive condition 0.41, Intransitive condition 0.40). But after about 2.5 s, performance in the two conditions begins to diverge; from 2.5 to 5 s from verb onset, toddlers in the Transitive condition prefer the causative scene (0.57) compared to those in the Intransitive condition (0.41).

To assess these patterns statistically, we first aggregated the proportion data from each time window (0–2.5 s, and 2.5–5 s from novel verb onset in the test query¹) into 50 ms bins (Barr, 2008). Following Barr, we then transformed the proportion data using an empirical-logit function, and fit the transformed data within each time window using a multi-level linear model treating Syntactic Condition (Transitive vs. Intransitive) as a fixed effect. The beta coefficients for the models are reported in Table 1.

The results of these analyses were straightforward. Syntactic Condition is a reliable predictor of looks to the causative scene in Window 2 but not Window 1. This effect of

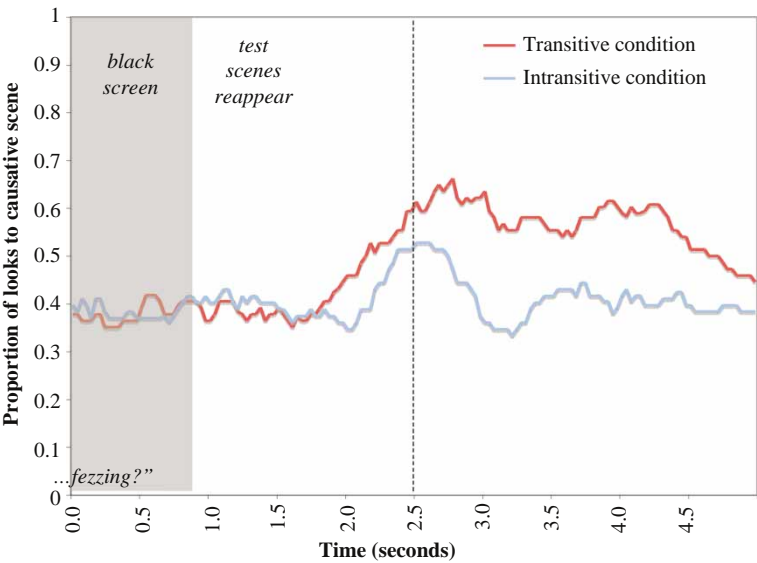


Figure 2. Depiction of time-course of toddlers’ looking time to the causative scene in response to the test question (e.g., “Where’s fezzing?”), depicted here from the onset of the novel verb.

¹Note that for approximately the first 1 s of Window 1, the screen was black; the test scenes were not visible. We nevertheless included this time period in our analysis to allow for the possibility that toddlers would launch anticipatory eye movements to the location in which the relevant test scene *had been* during the immediately preceding inspection period (Altmann, 2004).

TABLE 1
Fixed effects from best-fitting multi-level linear model of proportion of time spent looking at
causative scene (empirical logit transformed)

<i>Analysis with subject as random intercept</i>				
<i>Window</i>	<i>Effect</i>	<i>Estimate</i>	<i>SE</i>	<i>t-value</i>
0–2.5 s	Intercept	–0.51	0.22	–2.34*
	Syntactic condition (trans vs. intrans)	0.02	0.31	0.06
2.5–5 s	Intercept	–0.48	0.19	–2.56*
	Syntactic condition (trans vs. intrans)	0.80	0.27	3.01*
<i>Analysis with item as random intercept</i>				
<i>Window</i>	<i>Effect</i>	<i>Estimate</i>	<i>SE</i>	<i>t-value</i>
0–2.5 s	Intercept	–0.44	0.20	–2.17*
	Syntactic condition (trans vs. intrans)	0.08	0.06	1.36
2.5–5 s	Intercept	–0.39	0.38	–1.02
	Syntactic condition (trans vs. intrans)	0.70	0.07	10.18*

* $p < .05$ (on normal distribution).

Note: Models reported, with Syntactic condition as fixed effect, are significantly better fitting than models with no fixed effects, based on a chi-square test of the change in log likelihood.

syntactic condition held up in analyses with either Subjects or Items as a random intercept. The effect size in Window 2 is large, Cohen's $d = 0.8$.

DISCUSSION

Even before they have mastered transitive and intransitive syntactic constructions in their own productive speech, 21-month-olds successfully and spontaneously (1) establish an initial representation of a novel transitive verb based on syntactic information alone, and (2) retrieve this initial representation, however sparse it may be, at a later point when a candidate referent event is visible. Clearly, then, 21-month-olds “have what it takes” to benefit from cross-situational learning. They can glean whatever information is available about a novel verb in one encounter, and access that information in a subsequent encounter. Their initial representations for these novel verbs—formed on the basis of syntactic information alone—are clearly robust enough for later retrieval. This is a prerequisite for being able to add to these representations over multiple situations.

The results of the current experiment also contribute to our understanding of how quickly newly-learned lexical representations are retrieved from the mental lexicon. In previous work on speed of lexical retrieval of *familiar words* (e.g., *shoe*), Fernald et al. (1998) found that 2-year-olds require approximately 0.7 s from the onset of a familiar word to fixate the correct referent. In comparison, in the current study, toddlers required approximately 2.5 s.

There are several possible explanations for this relative delay in retrieval. First, an important factor in the speed of fixating a word's referent is lexical frequency (Dahan, Magnuson, & Tanenhaus, 2001). Because the current study introduces novel words (whose lexical frequency is a total of eight exposures), toddlers' representations for these novel words are likely to be fragile. This leads a clear prediction: If we presented toddlers with additional exposures to the novel words, for example by doubling the

number of dialogue scenes, their speed of retrieval should be faster. Second, in the current study, toddlers mapped the novel verbs to its referent *for the very first time* during the test phase. Again, a clear prediction arises: If some of the time toddlers required to fixate the causative scene was spent mapping the novel verb to meaning, then if we presented the novel verb again in a subsequent encounter, toddlers should require less time to fixate the referent.

Interestingly, despite the developmental decalage between noun acquisition and verb acquisition (e.g., Gentner, 1982; Gleitman, Cassidy, Papafragou, Nappa, & Trueswell, 2005; Waxman & Lidz, 2006), our results demonstrate that the time-course underlying 21-month-olds' response to novel verbs is comparable to their responses to novel nouns (Booth & Waxman, 2009). This similarity in response time is especially compelling in the current paradigm, where the test scenes provided the first opportunity for toddlers to identify a specific referent for the verb. This suggests that even if mapping a novel verb to meaning is more difficult than mapping a novel noun, once toddlers do succeed in mapping to meaning, they form similarly robust representations that the parser can access within a few seconds, and can use these to quickly identify a referent in the observable world. Toddlers' ability to access initial representations rapidly should serve them in good stead, especially when it comes to learning verbs. After all, the events described by most verbs, if present at all in the context of a conversation, are typically more fleeting than the concrete objects described by most nouns (Gentner, 1982; Gleitman, 1990).

Manuscript received 16 August 2011

Revised manuscript received 14 November 2011

First published online 12 March 2012

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