

## PAPER

# Semantic detail in the developing verb lexicon: An extension of Naigles and Kako (1993)

Sudha Arunachalam<sup>1</sup> | Shaun Dennis<sup>1,2</sup>

<sup>1</sup>Department of Speech, Language, and Hearing Sciences, Boston University, Boston, Massachusetts

<sup>2</sup>Department of Psychology, University of Bath, Bath, UK

**Correspondence**

Sudha Arunachalam, Department of Speech, Language, and Hearing Sciences, Boston University, Boston, MA 02215, USA.  
Email: sarunach@bu.edu

**Funding information**

The National Institutes of Health awards NIH R03HD067485 and NIH K01DC013306

**Abstract**

Verbs are often uttered before the events they describe. By 2 years of age, toddlers can learn from such an encounter. Hearing a novel verb in transitive sentences (e.g. *The boy lorped the cat*), even with no visual referent present, they later map it to a causative meaning (e.g. *feed*) (e.g. Yuan & Fisher, 2009). How much semantic detail does their verb representation include on this first, underinformative, encounter? Is the representation sparse, including only information for which they have evidence, or do toddlers make more specific guesses about the verb's meaning? In two experiments ( $N = 76$ , mean age 27 months), we address this using an event type studied by Naigles and Kako (1993); they found that when toddlers hear a novel transitive verb while simultaneously viewing a non-causative referent—a contact event such as patting—they map the verb to the contact event. In Experiment 1 we replicated this basic result. Further, toddlers' representations persisted over a 5-minute delay, manifesting again during a re-test. In Experiment 2, toddlers heard the verbs while watching two actors converse instead of while seeing contact events. At test, they showed no evidence of mapping the verbs to contact events, either initially or after a 5-minute delay, despite that in prior work they mapped verbs to causative events under identical circumstances. We infer that on hearing a novel verb in a transitive frame, absent a relevant visual scene, toddlers posit a more specific representation than the evidence requires—one that incorporates causative semantics. A video abstract of this article can be viewed at: <https://youtu.be/aRCqSTbr6Bw>

## 1 | INTRODUCTION

On a first encounter with a new word, a learner will only have access to some of the information required to form a complete lexical representation. A single experience may offer information about what one member of the category looks like, or a single sentential context in which the word appears. How detailed a representation do learners create on the basis of this limited experience? Do they make a specific guess about the word's meaning from whatever evidence is at hand, even if they cannot be sure it is correct, or do they entertain all possibilities that are compatible with the evidence until further information becomes available?

This question has primarily been addressed in the domain of noun acquisition and, specifically, in the acquisition of labels for objects. Researchers have disagreed about whether learners hearing a novel

word store multiple possible referents as they accrue evidence about which is correct (e.g. Smith & Yu, 2008; Yu & Smith, 2007), or initially propose a single specific meaning for a new word, even though their first encounter provides insufficient evidence to rule out other possibilities (e.g. Trueswell, Medina, Hafri, & Gleitman, 2013; Woodard, Gleitman, & Trueswell, 2016).

We present new evidence on this issue from verb learning. Verb learning presents an interesting test case because by 2 years of age, toddlers can use a relatively abstract cue to verb meaning: the syntactic frame in which the verb appears. This cue provides evidence about a verb's syntactic properties, which in turn are related to the verb's meaning in systematic ways (e.g. Levin, 1993). But syntactic context in itself does not pinpoint a specific event to which the verb refers; the most it can convey is a set of compatible event types, allowing us to



ask whether learners propose more specific semantic detail on a first encounter than is available from syntactic context alone.

Toddlers' use of syntactic context in verb acquisition—an ability known as syntactic bootstrapping—was demonstrated in a landmark study by Naigles (1990). Two-year-olds viewed two actors simultaneously engaged in a causative action and in synchronous actions: a duck pushed down on a bunny's head, forcing him to bend at the knees, while simultaneously, the duck and bunny each waved one arm in circles. During this familiarization, toddlers heard a novel verb in either a transitive frame, *The duck is gorping the bunny*, or an intransitive frame, *The duck and the bunny are gorping*. At test, the two events were pulled apart on separate screens, side-by-side. On one screen, the duck pushed the bunny, and on the other, the duck and bunny waved. The toddlers' preferences at test reflected the syntactic information they had heard; those who heard the transitive frame looked more at the causative scene as compared to those who heard the intransitive frame. This study and many others have established that toddlers use a verb's syntactic frame to acquire its meaning (e.g. Gleitman, 1990; Landau & Gleitman, 1985), and specifically have shown that toddlers have early and robust knowledge that transitive frames can describe causative events, in which one event participant acts on and affects another (e.g. Arunachalam, 2013; Arunachalam, Escovar, Hansen, & Waxman, 2013; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Fernandes, Marcus, Di Nubila, & Vouloumanos, 2006; Fisher, 1996, 2002; Jin & Fisher, 2014; Lee & Naigles, 2008; Lidz, Gleitman, & Gleitman, 2003; Messenger, Yuan, & Fisher, 2015; Naigles, 1996; Yuan & Fisher, 2009; Yuan, Fisher, & Snedeker, 2012).

In a clever follow-up to Naigles (1990), Naigles and Kako (1993) investigated whether the transitive-causative link identified in Naigles (1990) extended to contact events. Like causative events, contact events can be described with transitive frames (e.g. *Maria pats the dog*), and feature an agent making physical contact with a patient/theme. However, unlike causative events, the patient/theme does not undergo a change of state or location. In their Experiment 2, Naigles and Kako (1993) used the same paradigm as Naigles (1990), but replaced the causative events with contact events, such as an actor touching another actor's head with splayed fingers; an event depicting synchronous actions still served as the distractor (non-target) scene. Toddlers succeeded here too, demonstrating that they can not only assign novel transitive verbs to causative events, but also to contact events. Scott, Gertner, and Fisher (in press) found the same result with even younger toddlers (23 months). In Experiment 3, Naigles and Kako next pitted contact and causative events against each other, and although toddlers preferred to look at the causative event over the contact event, this preference was no greater than it was in a control condition in which no novel words were presented. Naigles and Kako took this to mean that even though toddlers preferred to look at causative events, they did not preferentially map the novel verb to the causative event because both events were plausible referents.

These results indicate that toddlers can use transitive syntax to assign novel verbs a contact meaning, if such a meaning is presented as a candidate. This finding is particularly interesting given

## RESEARCH HIGHLIGHTS

- Two-year-olds can learn verb meanings by hearing them in informative syntactic contexts while they view potential referents, and retain these meanings over a 5-minute delay.
- Two-year-olds hearing a new verb without visual access to a referent event establish a more specific representation than required by the evidence.

evidence that learners' early bias is to associate transitive frames with causative events (e.g. Bunker & Lidz, 2004; Lidz et al., 2003; Muentener & Lakusta, 2011; Slobin, 1981). Slobin (1981), for example, writes that grammar is initially used to encode prototypical causative events in which 'an agent willfully brings about a physical and perceptible change of state or location in a patient by means of direct body contact' (p. 189).

In the paradigm used by Naigles (1990) and Naigles and Kako (1993), toddlers had visual access to the novel verb's referent as they heard the novel verb. But one interesting challenge of verb acquisition is that verbs are rarely uttered during the event they describe (e.g. Gleitman & Gleitman, 1992; Tomasello & Kruger, 1992). If toddlers are to learn anything from such an encounter with a new verb, they have to form an initial representation from the sentence alone. They must then retain this interpretation long enough to benefit from additional linguistic or observational information that might come along to flesh out the representation. For example, hearing a verb in multiple syntactic frames can further constrain hypotheses about its meaning (e.g. Naigles, 1996, 1998); many causative verbs but not contact verbs can occur in intransitive frames with the patient argument in subject position (e.g. *The ball bounces*), while many contact verbs but not causative verbs can occur in intransitive frames with the agent argument in subject position (e.g. *The cat scratches*). Naigles (1996) found that female toddlers hearing novel verbs in both a transitive frame and one of these types of intransitive frame correctly mapped the verb to either a causative or contact meaning. However, it is likely that in naturalistic input, these multiple occurrences do not often occur in quick succession. Hoff-Ginsberg (1986) found that only 12% of maternal utterances repeated either a noun or a verb from the previous utterance, and Waterfall (2006) found that 28% of utterances repeated any open-class word (the number of repetitions of a verb in two different syntactic frames within two successive utterances is of course a subset of these instances). Thus, on most occasions, toddlers must form a representation on the first encounter that they can retain long enough to benefit from the second encounter, which may or may not occur within the same conversation.

Therefore, an important question remains: Can toddlers assign a novel verb to a contact meaning on a first encounter on the basis of a transitive syntactic frame alone, or is it only when the contact

scene is present as a candidate meaning that they can do so? We might expect that because of the early bias for transitive-causative mappings, toddlers hearing novel verbs in transitive frames initially prefer to assign the verbs a causative meaning, unless there is evidence available to them in the moment that suggests a different meaning is plausible.

In the current study we adapted Naigles and Kako's experiment by using a paradigm developed by Yuan and Fisher (2009) that allows us to examine the representations toddlers form from syntactic information alone. Instead of presenting novel verbs while the referent event was ongoing, Yuan and Fisher presented them in the context of conversations between two actors (e.g. 'Guess what? The boy is gonna *blick* the cat'). At test, toddlers viewed candidate referent events and were asked to choose between them. In this paradigm, the evidence in the learning situation is purely linguistic: the sentences contain informative syntactic structure and informative semantic content that provide information about the verb's argument and event structure. In Yuan and Fisher's investigation, toddlers successfully assigned novel transitive verbs to the causative event, even though they only had access to linguistic information when hearing the novel verb. Subsequent studies using this paradigm have shown the same result (e.g. Arunachalam, 2013; Arunachalam et al., 2013; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Gertner & Fisher, 2012; Jin & Fisher, 2014; Messenger et al., 2015; Yuan et al., 2012).

This paradigm is interesting for the question of what kind of initial mapping learners can make from limited evidence and, specifically, from linguistic information alone. What might the toddler's learning process look like in such a situation? At the outset, before hearing a verb or viewing a candidate event, toddlers are prepared to map new verbs that they encounter to myriad meanings, including events involving only one participant acting agentively (e.g. crying), events involving one participant undergoing a change of state (e.g. awakening), events involving two participants in a noncausal relation (e.g. hugging), events in which one participant acts causally on another, causing a change of state (e.g. spinning), and so on.<sup>1</sup> On hearing a novel verb in a transitive frame, absent a relevant visual scene, we know from prior work that toddlers rule out hypotheses that do not involve two event participants, like *coughing* or *laughing* (e.g. Messenger et al., 2015). However, the transitive frame leaves open several possible event types, including both causative and contact referents.

At one extreme, learners could choose a specific meaning, perhaps the first event that comes to mind in the context of the event participants they heard named in the sentence, for example, *feed*. We term this possibility Full Semantic Detail. But it is clear from the verb learning evidence that learners do not make such specific guesses; if this were the case, we would expect learners to only successfully identify the correct event at test if that event happened to be a feeding event. Instead, given that taken together, these studies have presented a range of causative events at test (e.g. bending, spinning, bouncing), we infer that the initial representation they form on the basis of syntactic structure alone is at least broad

enough to encompass a variety of causative events. In other words, when toddlers hear a novel verb in a transitive frame, absent other information, they posit meanings that are at least abstract enough to contain a causative semantic component without specifying a particular manner or result.

At the outer limit, then, how broad is the meaning toddlers assign to a novel transitive verb upon a first hearing? Is it the case that they allow the verb to encompass any event type that is compatible with transitive syntax, such as contact events? Few studies have examined children's acquisition of transitive verbs labeling non-causative events (Fisher & Song, 2006; Hartshorne, Pogue, & Snedeker, 2015; Naigles & Kako, 1993; Scott & Fisher, 2009; Scott et al., in press), and none of these have asked how learners assign meaning to a novel transitive verb from the syntactic frame alone, absent a visual referent. At the other extreme, then, it could be that learners extract only that the verb can be transitive and wait until the test phase to determine which test event is likely to be most compatible with this frame. The evidence thus far is compatible with this possibility, which we term the Minimal Semantic Detail hypothesis.

Intermediate possibilities exist as well. It could be that learners do include some semantic information in their representation for the novel verb, despite limited evidence. They could, for instance, posit that the verb refers to a particular event type, such as causative events, but exclude other kinds of events that can be described in transitive frames, such as contact events. We term this possibility the Moderate Semantic Detail hypothesis. Given that Full Semantic Detail cannot be correct, our goal in the current study is to provide evidence to adjudicate between the Minimal Semantic Detail and Moderate Semantic Detail hypotheses.

To assess this, we evaluated toddlers' visual attention toward contact and synchronous candidate scenes after hearing a novel verb in a transitive frame absent a relevant visual scene (with the intransitive frame serving as a control). If they have restricted their interpretation to causative meanings, and no causative events are shown, they should fail to show a preference for any mapping, because the candidate events are equally poor matches. This would indicate that their initial representation for the novel verb contains Moderate Semantic Detail, specifying causative semantics.

By contrast, if visual candidate events are presented simultaneously with the linguistic information, as in Naigles and Kako (1993), toddlers need not restrict their interpretation to causative events. The visual availability of a contact event referent, even if dispreferred relative to causative events as a referent for a transitive verb, should help toddlers recognize that the contact event, too, can be described in a transitive frame, like many of the verbs already in their vocabularies (e.g. hug, kiss).

We present two experiments. In Experiment 1, our goal was to replicate, using our own materials, Naigles and Kako's finding that when novel transitive verbs are presented *in conjunction* with a contact event as a possible referent, toddlers prefer this referent as compared to when they hear novel intransitive verbs. In Experiment 2, we used the dialogue-and-test paradigm developed by Yuan and Fisher (2009) to allow toddlers only linguistic



information, and no observational information, on which to base their representation for the novel verb; at test, they viewed the same events as in Experiment 1. We used the same dialogue-and-test procedure as in two published studies that document toddlers' success with the causative vs. synchronous event distinction (Arunachalam & Waxman, 2010; Arunachalam et al., 2013), but replacing the causative events with contact events. If toddlers map the novel verb to the contact event in both experiments, we would infer that in Experiment 2, linguistic information alone leads to a representation with Minimal Semantic Detail—that is, it could encompass multiple event types that are compatible with the transitive frame. If they succeed in Experiment 1, when the contact referent is available during Familiarization, but not in Experiment 2, when it is not, we would infer that the Moderate Semantic Detail hypothesis is correct—that is, toddlers' initial representations on hearing a novel transitive verb alone include a causative meaning component.

In both experiments we tested toddlers twice: once immediately after exposure to each novel verb, and again after a 5-minute delay during which toddlers played with blocks. During this second test, toddlers saw only the test phases from all novel verb trials; thus, we asked whether they could identify the novel verb's referent again after the delay with no additional exposure to the syntactic frame. Our goal with this retest was twofold. First, we wanted to expand the research on how newly acquired lexical representations fare over delays. While most word-learning research involves testing immediately after training, some studies incorporating delays between training and test have shown that representations decay very quickly (e.g. Horst & Samuelson, 2008). It may be, however, that representations formed on the basis of syntactic information alone, as in the present study, are more robust; Yuan and Fisher (2009) found that novel verb representations that toddlers formed from dialogues withstood delays of one or two days (see also He, Waxman, & Arunachalam, 2017). If toddlers succeed in mapping the verb to meaning in either experiment, this manipulation allows us to see whether the representation is robust enough to withstand a delay.

Second, we wanted to know whether delays specifically affect abstraction. There is some evidence that lexical representations become more abstract over delays such that only the 'gist' is preserved (e.g. Werchan & Gómez, 2014). In the context of Experiment 2, we wondered whether after a delay, toddlers' representations for the verbs would decay enough to lose the causative semantics while retaining the verb's syntactic properties. Thus, if toddlers initially *failed* to map the verbs to meaning in Experiment 2, because they posited a causative meaning, they might succeed after a brief delay, during which the semantic details they encoded about the verb's representation could decay. (Of course, the opposite is possible as well; toddlers could encode and retain causativity, forgetting other aspects of the verb's representation. Nevertheless, we pursued this hypothesis to ensure that we were not leaving this possibility aside.)

## 2 | EXPERIMENT 1

The goal of Experiment 1 was to replicate the basic finding from Naigles and Kako's (1993) second experiment, that toddlers who hear a novel verb in a transitive frame while concurrently viewing both contact and synchronous events will map the verb to the contact scene as compared to those hearing a novel verb in an intransitive frame.

### 2.1 | Methods

#### 2.1.1 | Participants

Thirty-eight toddlers (parent reported sex: 19 female, 19 male) with a mean age of 27.3 months (age range: 24.7 to 31.9 months) were included in the final sample. The sample size was selected based on prior work: Naigles and Kako (1993) had a sample size of 16 per condition, and Arunachalam and Waxman (2010) had 20 per condition. Toddlers were recruited from the greater Boston, MA region. They were reported to be typically developing by their parent, and were acquiring English natively, hearing other languages less than 30% of the time. Parents completed the MacArthur-Bates Communicative Development Inventory Short Form Level II A (Fenson et al., 2000). Toddlers' production vocabulary ranged from 19 to 100 words (mean 76 words) and did not differ between conditions (mean 80 words in the Intransitive condition and 72 words in the Transitive condition). An additional three toddlers were excluded from analysis and replaced in the design, two who contributed no data after trials were excluded for excessive track loss (see below), and one due to fussiness that prevented completion of the experiment. Of the 38 toddlers, 36 were amenable to completing a second test phase after a 5-minute delay.

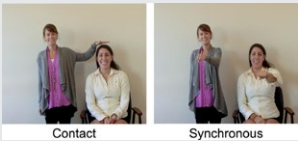
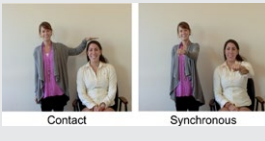

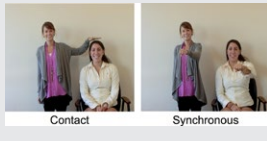



#### 2.1.2 | Materials

*Visual stimuli* were videos of actors performing actions (e.g. waving). On three trials, event participants were people, and on the fourth, they were a boy and a ball. Unlike Naigles and Kako (1993), in which toddlers heard novel verbs in the context of two actors simultaneously engaged in both a contact event and synchronous events, in our version toddlers saw two separate but simultaneously presented visual scenes, one depicting the two actors engaged in a contact event and the other depicting the same two actors engaged in synchronous events. (See Table 1.) These event scenes were identical to the ones toddlers later saw at test. *Auditory stimuli* were recorded in a sound booth by a female native speaker of American English using child-directed speech, and synchronized with the visual stimuli.

#### 2.1.3 | Apparatus and procedure

Procedures were approved by Boston University's Institutional Review Board (#2646E). Toddlers played with toys in our reception area while the parent completed paperwork, including the

**TABLE 1** Schematic illustration of one trial (of four)

Familiarization		Test		
		Baseline	Query	Response
Visual stimuli				
Experiment 1				
Experiment 2				
Auditory stimuli				
Transitive condition	The girl is lorping the lady.	Look!	Where's lorping?	Do you see lorping?
Intransitive condition	The girl and the lady are lorping.			

MacArthur-Bates checklist. They were then brought into the testing room, where the toddler sat in a car seat or on the parent's lap, 16 inches from a widescreen (24-inch) corneal reflection eye-tracker monitor (Tobii T60XL), which samples at 60 Hz. If the toddler sat in the car seat, the parent sat behind and to the side, out of tracking range, and if in the parent's lap, the parent wore a blindfold. The parent was asked not to speak during the video.

Toddlers viewed a 5-point calibration (Tobii Studio 2.0), and then participated in two warm-up trials featuring familiar characters and actions, and were asked about one of them (e.g. 'Where's dancing?'). These trials were intended to accustom toddlers to seeing two dynamic scenes simultaneously and being asked about one. No novel words were presented.

Then, toddlers participated in four experimental trials, each consisting of a Familiarization Phase and a Test Phase. See Table 1 for a schematic illustration of one trial from both experiments. Toddlers were randomly assigned to either the Transitive or Intransitive syntactic condition for all four trials. The visual stimuli were identical in both conditions. Only the auditory stimuli during the Familiarization Phase differed. The four trials were presented in reverse order for half of the participants; preliminary analyses showed no effects of trial order and we collapse across both in the reported results.

During the Familiarization Phase, toddlers viewed the two scenes simultaneously, side-by-side, with the critical audio featuring the novel verb in either a transitive frame (e.g. 'The girl is lorping the lady!') or an intransitive frame (e.g. 'The girl and the lady are lorping!'). The Test phase comprised three periods: Baseline, Query, and Response. During Baseline, toddlers saw the two test scenes simultaneously, side-by-side, with no novel words, but attention-getting language (e.g. 'Look!'), for 24 seconds. Then, during the Query period, the scenes disappeared, replaced by a centrally positioned yellow star designed to capture their gaze centrally and to allow them to hear the test query (e.g. 'Where's lorping?') without the distraction of the dynamic scenes. Finally, during the Response

period, the two scenes reappeared in their original locations and the test query repeated (e.g. 'Do you see lorping?').

After all four trials, we imposed a delay of approximately 5–7 minutes, during which the toddler played with blocks with the experimenter. A second experimenter kept time and alerted the first experimenter when 5 minutes were up; it often took another minute or two to clean up the blocks and reseat the toddler. Some parents interacted with their toddler during the delay. Neither the parent nor experimenter used the nonsense words or discussed the video, except for general requests made at clean-up like, 'Let's clean up so we can watch another funny video.'

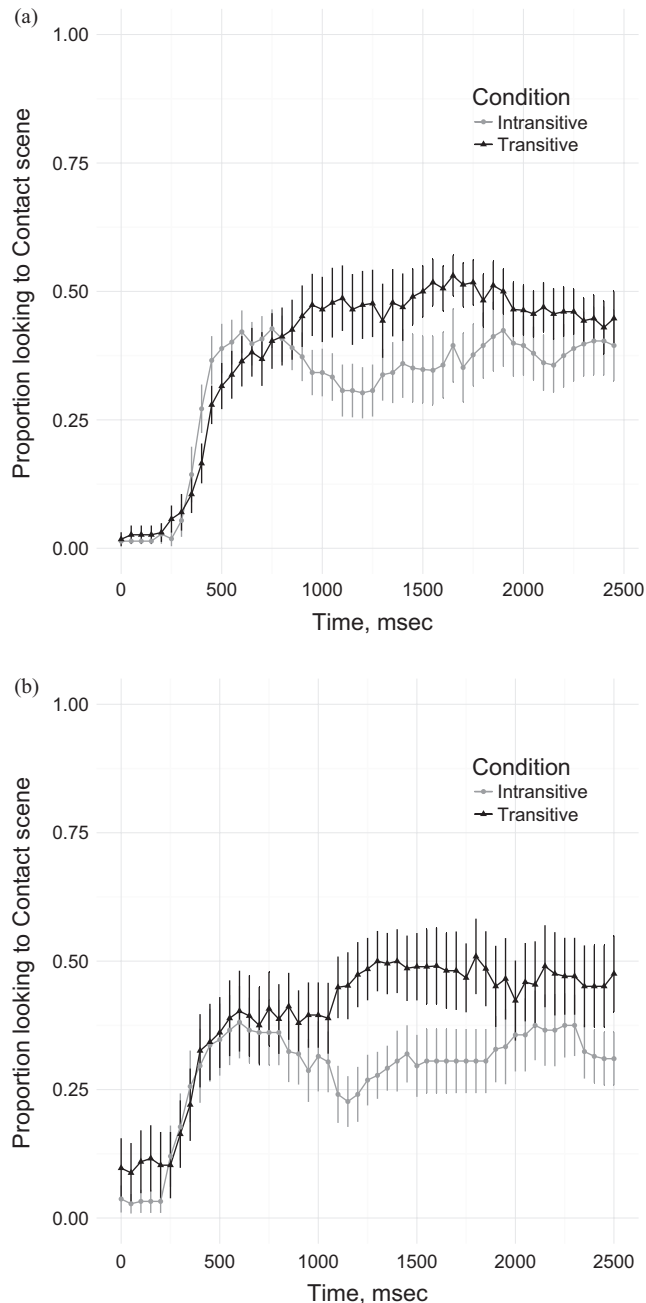
Finally, once toddlers were re-seated in front of the eye-tracker monitor and calibration was repeated, they viewed the second test phase, which was identical to the first. The Familiarization Phases were not repeated. Toddlers simply viewed the test phase from each trial in turn.

## 2.2 | Results

We first excluded from analysis trials on which there was more than 50% track loss in the analysis window (defined below); 91% of trials remained for the Pre-Delay test and 90% for the Post-Delay test. We also excluded all track loss data points (e.g. blinks) from further analysis. Looking to neither scene (e.g. between the two scenes) was included.

For the Baseline period of the Pre-Delay and Post-Delay tests, we predicted based on Naigles and Kako's (1993) Frameless condition—in which a novel verb was presented without syntactic information (e.g. *Gorping!*)—that toddlers would prefer the synchronous events scene regardless of condition assignment. Indeed, during the Baseline period of the Pre-Delay test, toddlers looked to the Synchronous scene 50% of the time (51% in the Intransitive condition and 49% in the Transitive condition), and to the Contact scene 44% of the time (43% in the Intransitive condition and 46%





**FIGURE 1** Gaze data from Experiment 1, split by syntactic condition, from the Response period of the Test phase in the Pre-Delay test (a) and Post-Delay test (b)

in the Transitive condition). (The remaining time consists of looks elsewhere, including between the two scenes.) The same pattern emerged in the Post-Delay test: toddlers looked to the Synchronous scene 51% of the time (51% in the Intransitive condition and 50% in the Transitive condition), and to the Contact scene only 42% of the time (42% in the Intransitive condition and 42% in the Transitive condition).

Of primary interest is where toddlers look during the Response periods, after being asked to find the referent of the novel verb, and specifically whether toddlers in the Transitive

condition prefer the contact scene compared to those in the Intransitive condition. Following prior work with this age group that presented causative and synchronous scenes instead of contact and synchronous scenes, we expect such a preference to emerge, if at all, during the period from 1 to 2.5 seconds of the Response period (e.g. Arunachalam, 2013); because the Response period is preceded by a centrally located star, it takes approximately 1 second for differences between linguistic conditions to emerge. This pattern is evident in Figure 1a, which depicts toddlers' attention to the Contact scene from 0 to 2.5 seconds of the Pre-Delay Response period, and in Figure 1b, which depicts gaze during the Post-Delay Response period after a 5-minute delay. We take this as evidence that toddlers mapped the novel verb to the contact scene and retained this representation over the delay.

To assess these patterns statistically, for each of the two test sessions (Pre-Delay and Post-Delay), we aggregated the data for looking to the contact scene into bins of 50 ms (three frames at 60 Hz), transformed the binned data using an empirical-logit function, and fit the transformed data using mixed-effects linear regression (Barr, 2008) with maximum likelihood estimation, using the lme4 package (version 1.1-12; Bates, Maechler, Bolker, & Walker, 2015) in R (version 3.3.0; R Core Team, 2014). Each model included a by-subject random intercept and slope for time (in seconds), a by-trial random intercept, and the following fixed factors: Time (in seconds), Condition (Transitive vs. Intransitive), the toddler's age (in months, centered around the mean), sex (female vs. male), and vocabulary score on the MCDI 2 Short Form (centered around the mean), and interactions. Note that for the Pre-Delay test, this model failed to converge; we instead ran a model with a simpler random effects structure, excluding the random slope for time (models with other simplifications to the random effects structure also converged and all showed the same pattern of significance). We compared the full models for each of the Pre-Delay and Post-Delay tests to simpler models using likelihood ratio testing with the drop1() function to assess significance of each term.

Table 2 lists the parameter estimates for the main effects from both models. (For full models and code see the Supporting Information.) The results match our predictions based on Naigles and Kako (1993): There is an effect of condition both before and after the 5-minute delay, indicating that toddlers successfully mapped the novel verb to the contact scene and retained their representation for the novel verb over the delay. There is also an effect of MCDI vocabulary score at both tests, and interactions of MCDI score with condition reveal that higher vocabulary is associated with more looking to the contact scene in the Transitive condition but not in the Intransitive condition. We pursued this vocabulary effect with correlations between proportion of looking to the Contact scene and MCDI score on just the data from the Transitive condition, which revealed a positive but not statistically significant correlation at the Pre-Delay test ( $R = 0.24$ ,  $p = 0.31$ ), and a positive and significant correlation at the Post-Delay

**TABLE 2** Model parameters for main effects from Experiment 1. For the full model specification and all parameter estimates including interactions, see the Supplementary Information

	Pre-Delay test			Post-Delay test		
	Estimate	Std. Error	t-value	Estimate	Std. Error	t-value
Intercept	2.03	0.083	24.38*	1.14	0.34	3.38*
Condition	0.37	0.16	2.33*	1.86	0.69	2.79*
Time	-0.19	0.047	-4.14*	0.26	0.15	1.70
Sex	-0.031	0.16	-0.19	-0.70	0.69	-1.04
Age	-0.0050	0.067	-0.075	0.19	0.29	0.65
MCDI	-0.030	0.0055	-5.55*	0.043	0.021	2.048*

Note. \* $p < 0.05$

test ( $R = 0.47$ ,  $p = 0.047$ ), suggesting that toddlers who are already good language learners (i.e. have higher expressive vocabularies) show better learning in our task (i.e. have stronger memories for the newly acquired words). There were no main effects of age or sex.

Thus, in Experiment 1 we replicated Naigles and Kako's finding that toddlers can use transitive syntax as an indicator of a contact scene referent and added a new finding that their representations for these novel verbs are robust enough to persist over a 5-minute delay.

### 3 | EXPERIMENT 2

Toddlers' success in Experiment 1 indicated that our visual scenes, like those in Naigles and Kako (1993), depicted clear contact and synchronous event referents that permit them to map novel transitive verbs to contact events when the linguistic stimuli and candidate referent events are presented concurrently. Our goal in Experiment 2 was to use the dialogue-and-test paradigm that has been used to demonstrate toddlers' robust abilities to map novel transitive verbs to *causative* events even in the absence of a concurrent visual scene (Arunachalam, 2013; Arunachalam & Waxman, 2010; Arunachalam et al., 2013; Jin & Fisher, 2014; Messenger et al., 2015; Yuan & Fisher, 2009). Toddlers viewed conversations between two actors in which they used a novel verb in either transitive or intransitive sentences, and then were asked to identify the referent of the novel verb at test, given a causative and synchronous scene. In the present study, we used the *very same design* with which toddlers have successfully mapped novel transitive verbs to causative events, but here we instead presented contact events, using the visual stimuli from Experiment 1.

#### 3.1 | Methods

##### 3.1.1 | Participants

A different group of 38 toddlers (18 female, 20 male) with a mean age of 28.0 months (age range: 25.0 to 32.9 months) was included. Vocabulary on the MacArthur-Bates Communicative Development Inventory Short Form Level II A (Fenson et al., 2000) ranged from 21 to 100 words (mean 77 words) and did not differ between conditions (mean 73 words in the Intransitive condition, 80 words in the

**TABLE 3** Dialogue from one trial (of four) in Experiment 2

Intransitive	<p>A: You know what?  B: What?  A: Suzy and the cat lorped.  B: Really? Suzy and the cat lorped?  A: And the girl and the lady are lorping.  B: Oh yes, they are lorping.  [laugh]  A: Guess what?  B: What?  A: Anna and the lady lorped.  B: Really? Anna and the lady lorped?  A: Yes, and the girl and my sister are going to lorp.  B: Mm, they are going to lorp.</p>
Transitive	<p>A: You know what?  B: What?  A: Suzy lorped the cat.  B: Really? Suzy lorped the cat?  A: And the girl is lorping the lady.  B: Oh yes, she is lorping her.  [laugh]  A: Guess what?  B: What?  A: Sam lorped the lady.  B: Really? Sam lorped the lady?  A: Yes, and the girl is gonna lorp my sister.  B: Mm, she is gonna lorp her.</p>

Transitive condition). An additional three toddlers were excluded from analysis and replaced in the design, two due to more than 50% track loss on more than half of the trials, and one due to fussiness. Of the 38 toddlers, 35 were amenable to completing a second test after a 5-minute delay.

##### 3.1.2 | Materials

Our materials were similar to those of Arunachalam et al. (2013) and Arunachalam and Waxman (2010), but the actors and actions shown at test were those used in Experiment 1. (See Table 1.) *Visual stimuli* during the Dialogue Phase consisted of video recordings of two actors conversing. (See Table 3.) *Auditory stimuli* for the Dialogue Phase were recorded simultaneously with the video recordings. The visual and auditory stimuli for the Test Phase were identical to Experiment 1.

### 3.1.3 | Apparatus and procedure

These were as in Experiment 1, except that the Familiarization on each trial consisted of dialogues instead of simultaneous presentation of scenes and sentences. During the Dialogue phase, two actors used the novel verb in eight sentences.

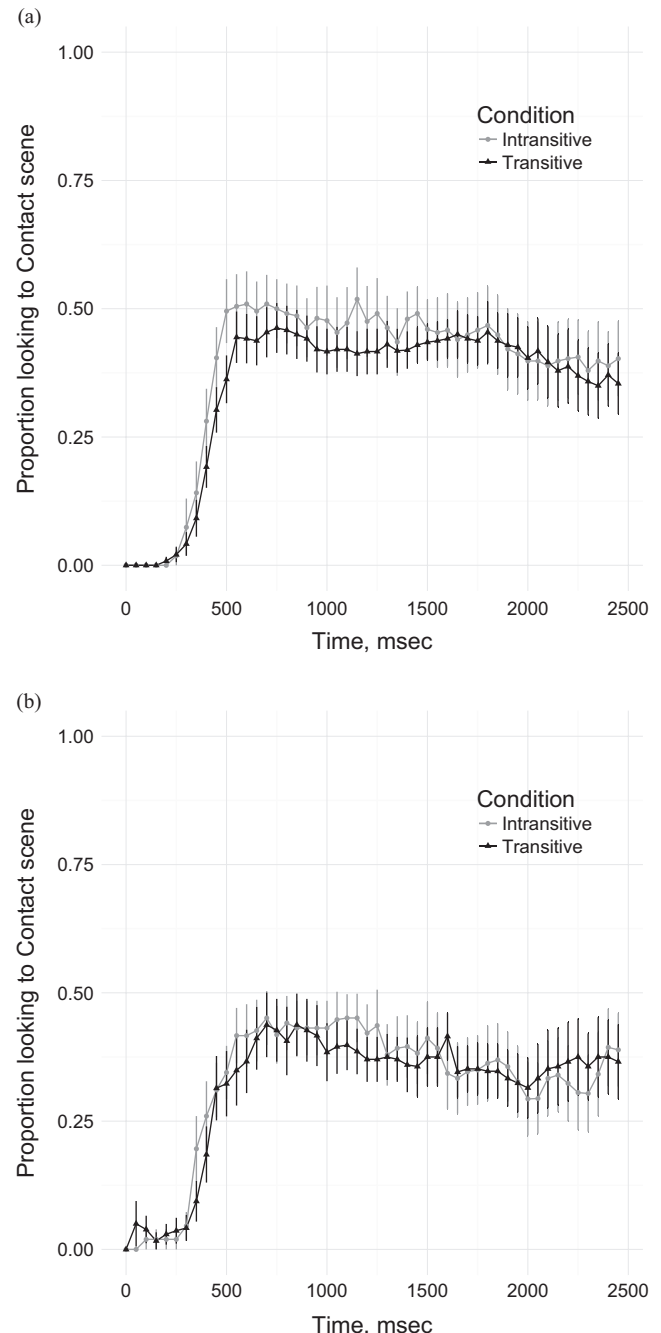
## 3.2 | Results and discussion

As in Experiment 1, we first excluded trials from analysis on which there was more than 50% track loss in the 1- to 2.5-second analysis window of the Response period; 88% of trials remained for the Pre-Delay test and 82% for the Post-Delay test. We again excluded all track loss data points (e.g. blinks) from further analysis.

During the Baseline period of each Test phase, before being asked to find the referent of the novel verb, toddlers behaved as in Experiment 1, preferring the synchronous events scene to the contact event scene. In the Pre-Delay test, they looked to the Synchronous scene 52% of the time (50% in the Intransitive condition and 52% in the Transitive condition), and to the Contact scene 42% of the time (42% in the Intransitive condition and 42% in the Transitive condition). In the Post-Delay test, toddlers looked to the Synchronous scene 49% of the time (48% in the Intransitive condition and 50% in the Transitive condition), and to the Contact scene 42% of the time (42% in the Intransitive condition and 42% in the Transitive condition).

Next, we compared toddlers' gaze behavior during the Response period. (See Figure 2.) Unlike in Experiment 1, there is no difference between conditions. We conducted the same analysis as for Experiment 1; see Table 4. (For full models and code see the Supporting Information.) Unsurprisingly given the patterns evident in Figure 2, there was no significant effect of Condition in either the Pre-Delay or Post-Delay test. (Main effects of sex and vocabulary in the Post-Delay test indicate that females and children with lower vocabularies continued to be interested in the synchronous events scene (as they were during Baseline); there were no significant correlations between proportion looking to the contact scene and vocabulary in the Transitive condition, although the positive correlation in the Post-Delay test is underpowered and perhaps suggestive: Pre-Delay test  $R = -0.027$ ,  $p = 0.91$ ; Post-Delay test  $R = 0.37$ ,  $p = 0.13$ .)

In a post-hoc analysis, we compared performance in the two experiments to each other; we included data from the Pre-Delay tests of Experiments 1 and 2 in a single model, with the same factors as in the previous analyses, and from the two Post-Delay tests in a second model. The Pre-Delay tests did not yield a main effect of Experiment or of Condition, indicating no significant difference between simultaneous and dialogue presentation conditions, but the Post-Delay tests did. (See Table 5, and the Supporting Information for the full models.) It is not entirely surprising that there was no effect in the Pre-Delay tests because although the structure of the two experiments was strongly parallel, there was one important difference: In Experiment 1, toddlers saw the visual stimuli during Familiarization,



**FIGURE 2** Gaze data from Experiment 2, split by syntactic condition, from the Response period of the Test phase in the Pre-Delay test (a) and Post-Delay test (b)

but in Experiment 2, the Test phase was their first exposure to the two scenes. Although we included a Baseline period at Test to allow toddlers to examine the scenes, it is reasonable that they would have different looking patterns during the Response period based on how visually familiar the test scenes were. It could be that both scenes were sufficiently familiar by the Post-Delay test to overcome this difference between the experiments, but the smaller amount of data from this second test (due to the attrition reported above) makes this interpretation tentative.



**TABLE 4** Model parameters for main effects from Experiment 2. For the full model specification and all parameter estimates including interactions, see the Supplementary Information

	Pre-Delay test			Post-Delay test		
	Estimate	Std. Error	t-value	Estimate	Std. Error	t-value
Intercept	1.97	0.17	11.26	2.22	0.26	8.52
Condition	0.065	0.34	0.19	0.51	0.52	0.99
Time	-0.23	0.12	-1.97	-0.58	0.16	-3.52*
Sex	0.21	0.34	0.64	1.22	0.52	2.35*
Age	-0.078	0.078	-0.99	-0.017	0.12	-0.14
MCDI	-0.0089	0.011	-0.78	-0.038	0.017	-2.24*

Note. \* $p < 0.05$

**TABLE 5** Model parameters for main effects and Condition  $\times$  Experiment interaction from model comparing Experiments 1 and 2. For the full model specification and all parameter estimates including interactions, see the Supplementary Information

	Pre-Delay test			Post-Delay test		
	Estimate	Std. Error	t-value	Estimate	Std. Error	t-value
Intercept	2.08	0.087	23.77	1.68	0.22	7.73
Condition	0.15	0.16	0.93	1.15	0.43	2.68*
Time	-0.28	0.061	-4.51*	-0.16	0.12	-1.40
Experiment	-0.16	0.16	-1.00	1.00	0.43	2.33*
Sex	0.088	0.16	0.54	0.30	0.43	0.71
Age	-0.054	0.057	-0.94	0.058	0.15	0.38
MCDI	-0.020	0.0054	-3.78*	0.0020	0.014	0.14
Condition $\times$ Experiment	-0.100	0.33	-0.31	-1.23	0.86	-1.43

Note. \* $p < 0.05$

The results indicate that when novel verbs are presented in the absence of a potential contact event referent, prior appearance in a transitive frame does not result in a preference for the contact event in the Transitive as compared to the Intransitive condition. This null result is striking given that the familiarization they were given is identical in quantity and quality to previous studies demonstrating toddlers' abilities to map novel transitive verbs to *causative* scenes under these same circumstances (Arunachalam et al. 2013; Arunachalam & Waxman, 2010).

## 4 | GENERAL DISCUSSION

In two experiments, we probed 2-year-olds' abilities to map novel transitive verbs to scenes depicting contact events. In Experiment 1, we found, as in Naigles and Kako's (1993) Experiment 2, that toddlers succeed when hearing novel verbs in transitive frames while a contact event referent is visually co-present, and further, that they retain these representations over a 5-minute delay. In Experiment 2, we used the same sentence types and event types, but presented the sentences first, in dialogues, and only afterward presented the candidate visual referents. The results offer insight into the lexical representations that 2-year-olds form on hearing a novel verb in an informative syntactic frame, but absent a relevant visual scene. Although previous work has shown that toddlers can map novel transitive verbs to causative events when the referents are not

co-present, and indeed, a number of different causative events that different studies have presented, the current study reveals that they do not map novel transitive verbs to contact events under identical experimental conditions—withstanding that contact events too can be described in transitive frames. We infer that toddlers' initial representations for the verbs, formed on the basis of linguistic context alone, are semantically specified to encode causation. We propose that when toddlers initially encounter a new verb, they incorporate this semantic detail into their lexical representation, even without positive evidence that it is correct.

Toddlers' representations thus occupy a middle ground in semantic specificity: they are both broad enough to permit a range of events as referents, as long as those events are causative, and specific enough to exclude other types of events. This result supports the Moderate Semantic Detail hypothesis over the Minimal Semantic Detail hypothesis, under which we would have expected toddlers to encode syntactic information but no relevant event information.

What develops after age 2 to allow learners to easily acquire verbs that denote other kinds of events? In fact, the current findings are not so far from adult behavior. Adults, too, initially posit a prototypical causal relation between agent and patient when presented with transitive sentences outside of context (e.g. Kako, 2006). Indeed, cross-linguistically, languages encode causative events with transitive frames but are much more variable in how contact events are encoded (e.g. Hopper & Thompson, 1982; Tsunoda, 1985). What likely differs between 2-year-olds and adults is that the toddlers are



unable to override their initial hypotheses even when arriving at the test phase, in which no causative referent is present. Although we gave toddlers two test sessions for each verb, and thus two opportunities to overcome their causative bias and map the novel verbs to contact events, they failed to revise their initial hypotheses on seeing the events available at test, suggesting that they may need more exposures or more ostensive or explicit evidence that their initial hypothesis was incorrect.

Of course, this failure to map novel verbs to contact events on an initial encounter with syntactic information alone does not entail that toddlers should struggle to acquire contact verbs. After all, both Naigles and Kako (1993) and our Experiment 1 verify that toddlers have no difficulty mapping a novel verb to a contact meaning if that contact meaning is already identified as a candidate; it is only when they are required to posit a meaning on the basis of one syntactic context that their representation is too specific to encompass contact events. When both visual and linguistic information are available, linguistic information can help toddlers to narrow down their hypothesis space for identifying the correct meaning of the verb. The learning problem in that case may therefore be to identify the best possible meaning of the ones available visually, rather than the broader hypothesis set indicated by the linguistic information alone (e.g. Gillette, Gleitman, Gleitman, & Lederer, 1999).

Additional exposures should also help toddlers overcome an initial causative bias. These additional exposures may come in the form of visual exposures to the event, or linguistic exposures to the verb in other syntactic contexts (Bunger & Lidz, 2004; Naigles, 1996, 1998; Scott & Fisher, 2009). Toddlers do hear verbs in multiple kinds of syntactic contexts (e.g. Naigles & Hoff-Ginsberg, 1995), and, as noted above, Naigles (1996) found that this helps them map novel verbs to contact events rather than causative events.

Recognizing the importance of multiple kinds of information for learning, we have focused on the sparse, initial representations that toddlers might posit from their initial encounter with a new verb. We think this learning is important to study because toddlers may not always be exposed to a verb in multiple informative frames within the short time frame examined in experimental studies. To benefit from additional information, whether linguistic or observational, about a novel verb's meaning, toddlers must form some kind of representation that they can retrieve on a second encounter. Therefore, in the current study, we focused on what happens when toddlers first encounter a verb in only one type of frame. Importantly, although several studies show poor retention of new word meanings after even brief delays (e.g. Bion, Borovsky, & Fernald, 2013; Horst & Samuelson, 2008), there is evidence that toddlers hearing novel verbs in dialogues can retain their initial representations for these verbs over delays of a few hours (He et al., 2017), or even two days (Yuan & Fisher, 2009). It may be that representations that incorporate a syntactic frame are sufficiently robust to benefit from hearing multiple frames over a period of time including delays. Thus, future research should examine whether toddlers can integrate the contributions of multiple syntactic frames (e.g. intransitive and transitive)

to assign a verb a contact meaning even if the two presentations are separated by a delay.

Although we tested the hypothesis that a 5-minute delay might allow toddlers to integrate the linguistic information they had received with the observational information available at test, thereby dropping the causative semantics from their initial representations, it was not. One possibility, supported by a recent study, is that this kind of abstraction requires sleep (Sandoval, Leclerc, & Gómez, 2017). Perhaps a longer delay with sleep would have permitted toddlers to 'forget' the causative semantic elements of their representations for the novel verbs. Some amount of forgetting is actually expected to help learners generalize words to apply to new exemplars (e.g. Werchan & Gómez, 2014), and forgetting may be particularly useful for acquiring verb meanings—where learners must extract the relation between event participants, largely generalizing over the event participants themselves. But causativity is a basic semantic component and is less likely to vary across exemplars of a verb referent. Longer delays with sleep may not, then, support toddlers' forgetting of this semantic component.

Because the semantic representation of a causative verb comprises multiple elements, we do not yet know precisely what semantic information toddlers encode in their initial representation. Consider a causative event in which a girl *spins* a boy. It includes two event participants, an agent and patient/theme, as well as event subcomponents—the *process* by which the girl acts, the *result* of the action, namely that the boy is spun, and the *causal* element itself which specifies the relation between the girl and the boy. Which of these do toddlers automatically encode in their representation of a new transitive verb? Hartshorne et al. (2015) find that even 4-year-olds have difficulty with the non-canonical mappings seen in certain psychological state predicates, for example, *fear*, in which the causer of the fear is realized in object rather than subject position. This suggests that toddlers will at least be sensitive to the predicted agent/patient mapping. But the differences between causative and contact events are much subtler. Some of the elements of causative events are common to contact events as well—both have an agent and patient/theme, and both have a process component. What differs is whether there is a resulting change in the patient/theme, and whether there is a causal relation between what the agent is doing and this resulting change.

We aim in future research to tease apart whether one or both of these components is automatically encoded when toddlers hear a new transitive verb. Some support for the hypothesis that the resulting change in the patient/theme is crucial comes from Schulz, Wymann, and Penner (2001), who argue that on positing a new verb representation, (typically developing) learners focus first *only* on the result subevent, ignoring all other semantic details. Our own work in progress suggests that infants do critically focus on result subevents in non-linguistic tasks, providing additional support for Schulz et al.'s conclusions (He & Arunachalam, 2017).

If, on the other hand, the *causal* component is what is crucial, we would predict that toddlers would fail to map transitive verbs heard in dialogues to events in which one event participant performed an



action, and another changed state, but there was no evident causal relation between them, for example, no spatial and/or temporal contiguity. Work by Bunger and Lidz (2006) and Kline, Snedeker, and Schulz (2017) indicates that toddlers do expect transitive sentences to describe events with spatiotemporal contiguity between the *process* and *result* subcomponents, but in neither study was a non-contiguous event pitted against a truly incompatible event such as the synchronous events used in the current study; in both cases non-contiguous and contiguous (canonically causative) events were pitted against each other at test. Thus, an interesting follow-up of these studies would be to see whether the spatiotemporal contiguity is a critical component of the toddler's representation, or simply a preferred interpretation when available.

Another important task for future work is to understand why toddlers would initially favor Moderate Semantic Detail. One possibility is simply the Goldilocks one: positing too much detail is too restrictive, requiring substantial correction, while positing too little detail is too permissive, yielding insufficient detail to permit a robust representation. This sort of general learning strategy could apply across the lexicon. Another possibility, that we have advocated here, is that the primacy, both developmentally and typologically, of the causative-transitive relation is what drives this initial hypothesis.

Finally, on a methodological note, these results shed light on the dialogue-and-test procedure developed by Yuan and Fisher (2009). One question raised by their and subsequent studies is whether, on hearing a novel verb in conversations absent a relevant visual event, toddlers simply remember the syntactic context and wait until the test phase to perform a semantic mapping, or whether they immediately posit a lexical and lexico-semantic/syntactic representation for the novel verb. Toddlers' failure to map verbs to contact scenes in the present study suggests that it is the latter. If toddlers had only extracted syntactic information, they should have been able to map the novel verbs to contact scenes, as Naigles and Kako's and our Experiment 1 results (and the content of their own productive vocabularies, which include contact verbs such as 'hug' and 'kiss'; Fenson et al., 2000) indicate that 2-year-olds do know that transitive verbs can describe contact events. Rather, that they did not suggests that they had extracted from the dialogues a representation that included semantic information (e.g. causative event) that they were not able to override. Given that in naturalistic exposure, toddlers more often than not hear verbs in the absence of the event they describe (e.g. Tomasello & Kruger, 1992), this dialogue method provides a critical tool to reveal how they set down representations for these verbs, and what these representations look like. Our results document that the representations children form when no visual information is co-present can differ in critical ways from the representations they form when visual information is co-present.

## ACKNOWLEDGEMENTS

This research was funded by the National Institutes of Health awards NIH R03HD067485 and NIH K01DC013306. The content is solely the responsibility of the authors and does not necessarily

represent the official views of the National Institutes of Health. We are grateful to the research assistants at Boston University's Child Language Lab, to the reviewers, and to the participating families.

## ENDNOTE

- <sup>1</sup> Note that some imaginable meanings that rarely occur in the world's languages may not occur in the candidate set, such as confluations of manner and path in a single lexical item (e.g. Levin & Rappaport Hovav, 1991) or confluations of motion and ground (e.g. Talmy, 1985).

## REFERENCES

- Arunachalam, S. (2013). Two-year-olds can begin to acquire verb meanings in socially impoverished contexts. *Cognition*, 129, 569–573.
- Arunachalam, S., Escovar, E., Hansen, M.A., & Waxman, S.R. (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.
- Arunachalam, S., & Waxman, S.R. (2010). Meaning from syntax: Evidence from 2-year-olds. *Cognition*, 114, 442–446.
- Barr, D.J. (2008). Analyzing 'visual world' eyetracking data using multilevel logistic regression. *Journal of Memory and Language*, 59(4), 457–474.
- Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48.
- Bion, R.A., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word-object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition*, 126(1), 39–53.
- Bunger, A., & Lidz, J. (2004). Syntactic bootstrapping and the internal structure of causative events. In *Proceedings of the 28th Annual Boston University Conference on Language Development* (Vol. 28, pp. 74–85). Somerville, MA: Cascadia Press.
- Bunger, A., & Lidz, J. (2006). Constrained flexibility in the acquisition of causative verbs. In *Proceedings of the 30th Annual Boston University Conference on Language Development* (pp. 61–70).
- Dautriche, I., Cristia, A., Brusini, P., Yuan, S., Fisher, C., & Christophe, A. (2014). Toddlers default to canonical surface-to-meaning mapping when learning verbs. *Child Development*, 85(3), 1168–1180.
- Fenson, L., Pethick, S., Renda, C., Cox, J.L., Dale, P.S., & Reznick, J. (2000). Short-form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics*, 21(1), 95–115.
- Fernandes, K.J., Marcus, G.F., Di Nubila, J.A., & Vouloumanos, A. (2006). From semantics to syntax and back again: Argument structure in the third year of life. *Cognition*, 100(2), B10–B20.
- Fisher, C. (1996). Structural limits on verb mapping: The role of analogy in children's interpretations of sentences. *Cognitive Psychology*, 31(1), 41–81.
- Fisher, C. (2002). Structural limits on verb mapping: The role of abstract structure in 2.5-year-olds' interpretations of novel verbs. *Developmental Science*, 5(1), 55–64.
- Fisher, C., & Song, H.J. (2006). Who's the subject? Sentence structure and verb meaning. In K. Hirsh-Pasek & R.M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 392–425). Oxford: Oxford University Press.
- Gertner, Y., & Fisher, C. (2012). Predicted errors in children's early sentence comprehension. *Cognition*, 124(1), 85–94.
- Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition*, 73(2), 135–176.

- Gleitman, L. (1990). The structural sources of verb meanings. *Language Acquisition*, 1(1), 3–55.
- Gleitman, L., & Gleitman, H. (1992). A picture is worth a thousand words: The role of syntax in vocabulary acquisition. *Current Directions in Psychological Science*, 1, 31–35.
- Hartshorne, J.K., Pogue, A., & Snedeker, J. (2015). Love is hard to understand: The relationship between transitivity and caused events in the acquisition of emotion verbs. *Journal of Child Language*, 42(03), 467–504.
- He, A.X., & Arunachalam, S. (2017). *How we conceptualize the ends of events (and what it might mean for verb acquisition)*. Paper presented at the 14th International Congress for the Study of Child Language (IASCL), Lyon, France.
- He, A.X., Waxman, S.R., & Arunachalam, S. (2017). *Two-year-olds consolidate verb meanings during a nap*. Paper presented at the 2017 Cognitive Development Society Biennial Meeting (CDS), Portland, OR.
- Hoff-Ginsberg, E. (1986). Function and structure in maternal speech: Their relation to the child's development of syntax. *Developmental Psychology*, 22(2), 155–163.
- Hopper, P.J., & Thompson, S.A. (Eds.) (1982). *Syntax and semantics 15: Studies in transitivity*. New York: Academic Press.
- Horst, J.S., & Samuelson, L.K. (2008). Fast mapping but poor retention in 24-month-old infants. *Infancy*, 13, 128–157.
- Jin, K.S., & Fisher, C. (2014). Early evidence for syntactic bootstrapping: 15-month-olds use sentence structure in verb learning. In *Boston University Conference on Language Development*. Boston, MA: Cascadilla Press.
- Kako, E. (2006). The semantics of syntactic frames. *Language and Cognitive Processes*, 21(5), 562–575.
- Kline, M., Snedeker, J., & Schulz, L. (2017). Linking language and events: Spatiotemporal cues drive children's expectations about the meanings of novel transitive verbs. *Language Learning and Development*, 13(1), 1–23.
- Landau, B., & Gleitman, L.R. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.
- Levin, B. (1993). *English verb classes and alternations: A preliminary investigation*. Chicago: University of Chicago Press.
- Levin, B., & Rappaport Hovav, M. (1991). Wiping the slate clean: A lexical semantic exploration. *Cognition*, 41, 123–151.
- Lidz, J., Gleitman, H., & Gleitman, L.R. (2003). Understanding how input matters: Verb-learning and the footprint of universal grammar. *Cognition*, 87, 151–178.
- Messenger, K., Yuan, S., & Fisher, C. (2015). Learning verb syntax via listening: New evidence from 22-month-olds. *Language Learning and Development*, 11(4), 356–368.
- Muentener, P., & Lakusta, L. (2011). The intention-to-CAUSE bias: Evidence from children's causal language. *Cognition*, 119(3), 341–355.
- Naigles, L.R. (1990). Children use syntax to learn verb meaning. *Journal of Child Language*, 17, 357–374.
- Naigles, L.R. (1996). The use of multiple frames in verb learning via syntactic bootstrapping. *Cognition*, 58, 221–251.
- Naigles, L.R. (1998). Developmental changes in the use of structure in verb learning: Evidence from preferential looking. *Advances in Infancy Research*, 12, 298–317.
- Naigles, L.R., & Hoff-Ginsberg, E. (1995). Input to verb learning: Evidence for the plausibility of syntactic bootstrapping. *Developmental Psychology*, 31(5), 827–837.
- Naigles, L.R., & Kako, E.T. (1993). First contact in verb acquisition: Defining a role for syntax. *Child Development*, 64, 1665–1687.
- R Core Team (2014). R: A language and environment for statistical computing. R. Foundation for Statistical Computing, Vienna, Austria. URL: <http://www.R-project.org>
- Sandoval, M., Leclerc, J.A., & Gómez, R.L. (2017). Words to sleep on: Naps facilitate verb generalization in habitually and nonhabitually napping preschoolers. *Child Development*, 88(5), 1615–1628.
- Schulz, P., Wymann, K., & Penner, Z. (2001). The early acquisition of verb meaning in German by normally developing and language impaired children. *Brain and Language*, 77(3), 407–418.
- Scott, R.M., & Fisher, C. (2009). Two-year-olds use distributional cues to interpret transitivity-alternating verbs. *Language and Cognitive Processes*, 24(6), 777–803.
- Scott, R.M., Gertner, Y., & Fisher, C. (in press). Not all subjects are agents: Transitivity and meaning in early language comprehension. In K. Syrett & S. Arunachalam (Eds.), *Semantics in acquisition*. Amsterdam: John Benjamins.
- Slobin, D.I. (1981). The origin of grammatical encoding of events. In W. Deutsch (Ed.), *The child's construction of language* (pp. 185–199). London: Academic Press.
- Smith, L., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition*, 106, 1558–1568.
- Talmy, L. (1985). Lexicalization patterns: Semantic structure in lexical forms. In T. Shopen (Ed.), *Language typology and syntactic description, Vol. III. Grammatical categories and the lexicon* (pp. 57–149). Cambridge: Cambridge University Press.
- Tomasello, M., & Kruger, A.C. (1992). Joint attention on actions: Acquiring verbs in ostensive and non-ostensive contexts. *Journal of Child Language*, 19, 311–333.
- 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.
- Tsunoda, T. (1985). Remarks on transitivity. *Journal of Linguistics*, 21, 385–396.
- Waterfall, H.R. (2006). *A little change is a good thing: Feature theory, language acquisition and variation sets*. Doctoral dissertation, University of Chicago.
- Werchan, D.M., & Gómez, R.L. (2014). Wakefulness (not sleep) promotes generalization of word learning in 2.5-year-old children. *Child Development*, 85(2), 429–436.
- Woodard, K., Gleitman, L.R., & Trueswell, J.C. (2016). Two- and three-year-olds track a single meaning during word learning: Evidence for propose-but-verify. *Language Learning and Development*, 12(3), 252–261.
- Yu, C., & Smith, L.B. (2007). Rapid word learning under uncertainty via cross-situational statistics. *Psychological Science*, 18, 414–420.
- Yuan, S., & Fisher, C. (2009). 'Really? She blicked the baby?': Two-year-olds learn combinatorial facts about verbs by listening. *Psychological Science*, 20, 619–626.
- Yuan, S., Fisher, C., & Snedeker, J. (2012). Counting the nouns: Simple structural cues to verb meaning. *Child Development*, 83(4), 1382–1399.

## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**How to cite this article:** Arunachalam S, Dennis S.

Semantic detail in the developing verb lexicon: An extension of Naigles and Kako (1993). *Dev Sci*.

2019;22:e12697. <https://doi.org/10.1111/desc.12697>