



Brief article

Infants use known verbs to learn novel nouns: Evidence from 15- and 19-month-olds



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ABSTRACT

Fluent speakers' representations of verbs include semantic knowledge about the nouns that can serve as their arguments. These "selectional restrictions" of a verb can in principle be recruited to learn the meaning of a novel noun. For example, the sentence *He ate the carambola* licenses the inference that *carambola* refers to something edible. We ask whether 15- and 19-month-old infants can recruit their nascent verb lexicon to identify the referents of novel nouns that appear as the verbs' subjects. We compared infants' interpretation of a novel noun (e.g., the *dax*) in two conditions: one in which *dax* is presented as the subject of animate-selecting construction (e.g., *The dax is crying*), and the other in which *dax* is the subject of an animacy-neutral construction (e.g., *The dax is right here*). Results indicate that by 19 months, infants use their representations of known verbs to inform the meaning of a novel noun that appears as its argument.

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1. Introduction

Upon hearing the sentence *He ate the carambola*, fluent speakers of English would infer that *carambola* refers to something edible. And upon hearing the sentence *He ate his piano*, they would assume either that the sentence is nonsense or that an unconventional *eating* metaphor has been invoked. These inferences are guided by the verb *eating*'s "selectional restrictions" – the semantic requirements that this verb places on its arguments (Chomsky, 1965; Jackendoff, 1990; Katz & Fodor, 1963; Pinker, 1989; Resnik, 1996). In this paper, we ask whether infants can use their knowledge of verbs' selectional restrictions to inform the meaning of a novel noun that appears as its argument.

Although infants occasionally violate selectional restrictions in their spontaneous productions (Bowerman, 1978, 1982), they nonetheless appreciate the selectional

restrictions of at least some verbs by their second birthday (Friedrich & Friederici, 2005; Naigles, Hoff, & Vear, 2009; Valian, Prasada, & Scarpa, 2006). For example, when 26- and 30-month-olds are presented with two images (e.g., a cookie and a book), they are faster to fixate on the cookie when they hear a sentence such as *Eat the cookie* than *Take the cookie* (Fernald, Zangl, Portillo, & Marchman, 2008; Mani & Huettig, 2012). By this age, they can also use known verbs to identify the referents of otherwise ambiguous pronouns (e.g., *Which one can you drive?*) and can rapidly acquire the selectional restrictions of a novel verb from the contexts in which it occurs (Yuan, Fisher, Kandhadai, & Fernald, 2011). Together, these accomplishments reveal that infants successfully use the selectional restrictions of known verbs in sentence processing.

What is less clear is whether infants can use a known verb's selectional restrictions to hone in on the meaning of a novel noun that appears as its argument. Only one study has addressed this directly, and its results are promising. Goodman, McDonough, and Brown (2008) introduced infants to a novel noun alongside a known verb (e.g., *Mommy feeds the ferret*). Next, they presented infants

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with images of four objects (e.g., one animal and three artefacts) and said, for example, *Show me the ferret*. Infants at 24 and 30 months successfully recruited the verbs' selectional restrictions, selecting the animate object as the referent of the novel noun. Despite some methodological limitations (e.g., using familiar English words, presenting an “oddball” animate target amongst 3 inanimate distractors), these data suggest that 2-year-olds may indeed use the selectional restrictions of a known verb to infer the meaning of a novel noun.

In the present study, we ask whether a known verb can inform infants of the animacy status of its subject. To address this, we compare infants' interpretation of a novel noun (e.g., *dax*) in an Informative condition, where *dax* was presented as the subject of an animate-selecting verb (e.g., *The dax is crying*) to their interpretation in a Neutral condition, where *dax* was presented in an animacy-neutral construction (e.g., *The dax is right here*). We designed a new eyetracking paradigm that permits us to advance previous work in several ways. First, it permits us to consider the capacities of younger infants (15- and 19-month-olds) who, by all estimates, have only a modest stock of verbs. Second, it permits us to ask whether infants' linguistic representations of these verbs are robust enough to guide their selection of a referent for a novel noun that appears later as its argument. Inspired by recent designs (e.g., Arunachalam & Waxman, 2010; Yuan & Fisher, 2009), we introduce known verbs in the absence of any candidate referents for the novel noun. Third, we control for infants' existing word knowledge by presenting nonce words, and minimize demand characteristics by offering only two candidate referents at test (cf., Goodman et al., 2008).

2. Methods

2.1. Participants

Fifty-nine infants were included in the final sample, 30 19-month-olds ($M = 19.62$ months, ranging 18.0–21.85; 16 F) and 29 15-month-olds ($M = 15.60$ months, ranging 14.20–17.82; 12 F). They were recruited from the greater Evanston, IL area and acquiring English as their first language, with no more than 25% exposure to another language. Caregivers completed the MacArthur Short Form Vocabulary Checklist: Level II (Form A) (Fenson et al., 1993) as well as a supplementary checklist that asked which of the familiar verbs used in this design were known by their infant (see Table 1). Another 24 participants were excluded and replaced due to fussiness (14), technical

failure (8), or experimenter error (2). One 15-month-old (Informative condition) who was initially included in the analysis did not contribute data in any trials (due to tracking); he was therefore excluded but not replaced.

2.2. Apparatus

A Tobii T60XL corneal-reflection eyetracker was used for stimulus presentation and data collection. The eyetracker has a sampling rate of 60 Hz, and a display size of 57.3×45 cm.

2.3. Materials (Fig. 1)

2.3.1. Visual stimuli

Each trial consisted of three phases: Preview, Dialogue and Test. In the Preview phase (6s), infants saw images of two objects (one animal, one artefact) presented side-by-side on the screen. In the Dialogue phase (9s), an abstract screensaver was displayed on the screen. In the Test phase (6s), the two images from the preview phase reappeared in the same left–right positions on the screen.

2.3.2. Auditory stimuli

Two native speakers of American English – one female and one male – produced the linguistic materials using child-directed speech.

2.3.3. Stimulus selection

We used vocabulary norms (Dale & Fenson, 1996) as a guide in selecting both the visual and linguistic materials. For the familiar trials, we selected target objects whose names are understood by at least 72% of 15-month-olds (nouns: *bird, bottle, cow, dog, horse, spoon*). For the unfamiliar trials, we selected objects whose names infants would not know (abstract sculptured artefacts and exotic animals). Finally, we introduced novel names for these objects in sentences containing familiar verbs that are understood by 66% of 15-month-olds (*cry, dance, drink, eat, look, sleep*).

2.4. Procedure (Fig. 1)

After completing the vocabulary checklists, caregivers accompanied their infants to a testing room. Infants were seated on the caregivers' lap approximately 60 cm from the monitor. Caregivers, who wore opaque glasses to prevent them from viewing the images on the screen, were instructed not to speak or point during the experiment. After a standard five-point eyetracking calibration routine, the

Table 1
Participant summary.

	Vocabulary		Looking times (s)			
	MCDI	Known verbs	Familiar trials		Unfamiliar trials	
			Mean (SD)	Min.	Mean (SD)	Min.
15 months	6.69	4.3	4.18 (1.39)	1.39	3.24 (1.78)	–
19 months	17.5	4.9	4.51 (1.17)	2.18	4.23 (1.46)	1.31

Note: MCDI represents the mean number of words (out of a total 89) that caregivers judged that their infants produced. Known Verbs represents the average number of verbs (out of the 6 included in this experiment) that caregivers of infants in the Informative condition judged that their infants comprehended.

experiment began. Each infant participated in 12 trials: 6 familiar followed by 6 unfamiliar trials. For the unfamiliar trials, infants were randomly assigned to either the Informative or Neutral condition (between-subjects).

2.5. Familiar trials

The familiar trials were identical for all infants. First, in the Preview phase, infants saw an image of a familiar animal and artefact presented side-by-side (L/R position was counterbalanced across trials). After a 1s preview, they heard, “Oh wow! Look here!” Next, in the Dialogue phase, the objects disappeared; infants saw an abstract screensaver while listening to a dialogue in which the speakers mentioned one of the images by name (either the animal or the artefact) using neutral syntax (e.g., *The dog/bottle is right here*; see [Appendix A](#) for example scripts). Finally, in the Test phase, the familiar images from the Preview phase re-appeared in their original location; infants were prompted to find the object that had been mentioned previously in the dialogue (e.g., *Where is the dog/bottle?*) The onset of the target noun occurred 500 ms into this phase.

2.6. Unfamiliar trials

The structure of the unfamiliar trials was identical to that of the familiar trials, with two exceptions: (1) the two objects were unfamiliar, and (2) the nouns introduced during dialogue and test were nonce words. Infants in both the Informative and Neutral conditions saw the same unfamiliar images and heard the same linguistic materials during the Preview and Test phases. The only difference was in the linguistic information presented in the Dialogue phase (see [Appendix A](#) for example scripts). In the Informative condition, infants heard a novel noun in the subject position of a known verb that selected for an animate agent (e.g., *The dax is crying*); in the Neutral condition, infants heard the same noun in a sentence that did not select for either an animate or inanimate referent (e.g., *The dax is right here*). Notice that the only difference between the conditions was in the linguistic information provided during the Dialogue phase, and that during this phase, no candidate referents for the novel noun were available.

3. Analysis

3.1. Data preparation

We focused our analysis on the window beginning at the onset of the target word at test and lasting through the end of the trial (5.5s total). For each trial, an 811px by 713px area of interest (AOI) was defined around each of the object images. Gazes outside these areas were excluded from analysis, as were trials in which an infant's total looking time was significantly lower (2+ SD) than their age group's mean. Infants in both age groups contributed an average of at least 5.5 trials in both familiar and unfamiliar trials.

We calculated, for each trial of each infant, the proportion of looking time devoted to the animal [looking to

animal/(looking to animal + artefact)] throughout the analysis window. This yielded up to 12 data points for each infant (6 familiar, 6 unfamiliar trials). These proportions were arcsine-root transformed and served as our dependent measure.

3.2. Model fitting

To assess the contribution of age and condition to infants' performance, we compared maximal-likelihood linear mixed-effects models with and without each factor using -2 log-likelihood ratio tests ([Baayen, Davidson, & Bates, 2008](#)). Factors were deviation-coded prior to model fitting. Trials' and participants' estimated intercepts were entered as random effects. Traditional ANOVAs yielded the same results.

3.3. Timecourse

To assess the timecourse of infants' attention to the animal and artefact images, data were aggregated by condition into a series of 250 ms bins. These were compared sequentially using ANOVAs to identify any stable time period during which infants' looking in the two conditions diverged.

3.4. Predictions

We predicted that infants would overall prefer to look at animals over artefacts ([Childers & Echols, 2004](#); [Fernald et al., 2008](#); [LoBue, Pickard, Sherman, Axford, & DeLoache, 2013](#)), but that this preference would be moderated by the linguistic information presented in the dialogues. On familiar trials, we reasoned that if the design is sufficiently sensitive, infants' looking patterns should be guided by the known target word: they should devote more attention to the animal when prompted with its name than with the name of the artefact. Infants' performance on these trials provides a proof of the design. On unfamiliar trials, we reasoned that if infants can recruit known verbs to identify the referent of a novel noun, then infants in the Informative condition should devote more attention to the novel animal than should those in the Neutral condition.

4. Results

As predicted, on familiar trials, infants' overall preference for the animal ($M_{19\text{-months}} = .60$, $M_{15\text{-months}} = .63$) was moderated by the target words they heard (see [Fig. 2](#)). At 19 months, infants looked significantly more towards the animal when prompted with its name ($M = .79$, $SD = .11$) than with the name of the artefact ($M = .42$, $SD = .16$), $\beta = .45$, $SE = .04$, $\chi^2(1) = 20.11$, $p < .001$. The same was true at 15 months (animal named: $M = .77$, $SD = .11$; artefact named: $M = .49$; $SD = .18$), $\beta = .33$, $SE = .07$, $\chi^2(1) = 10.38$, $p = .001$, although this effect was less pronounced than at 19 months, $\beta_{\text{Age*Target}} = .12$, $SE = .06$, $\chi^2(1) = 4.28$, $p = .04$. An analysis of the timecourse (see [Fig. 3](#)) revealed that at both ages, infants rapidly directed their visual attention

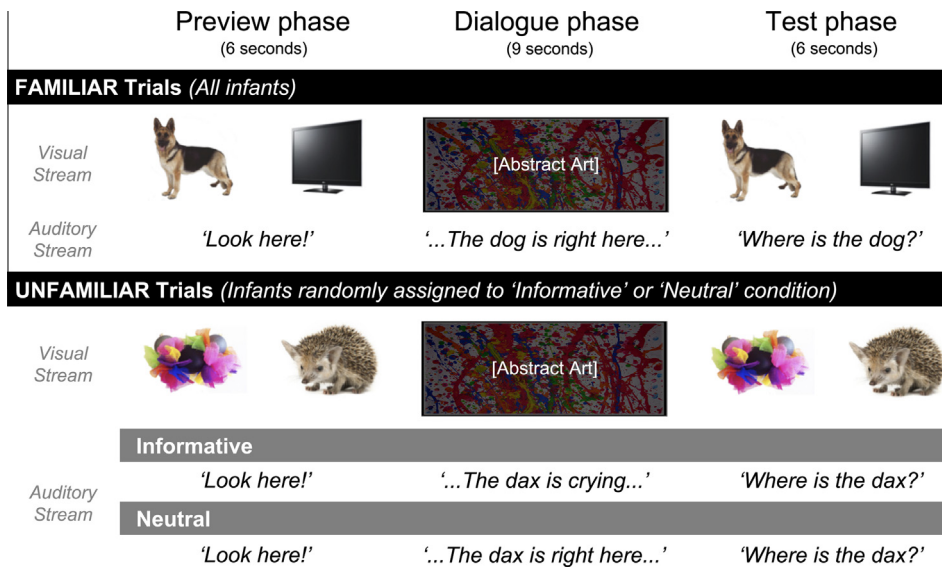


Fig. 1. A schematic of the experimental design, illustrating the visual and auditory streams of information presented during each phase (Preview, Dialogue, Test) on Familiar and Unfamiliar trials.

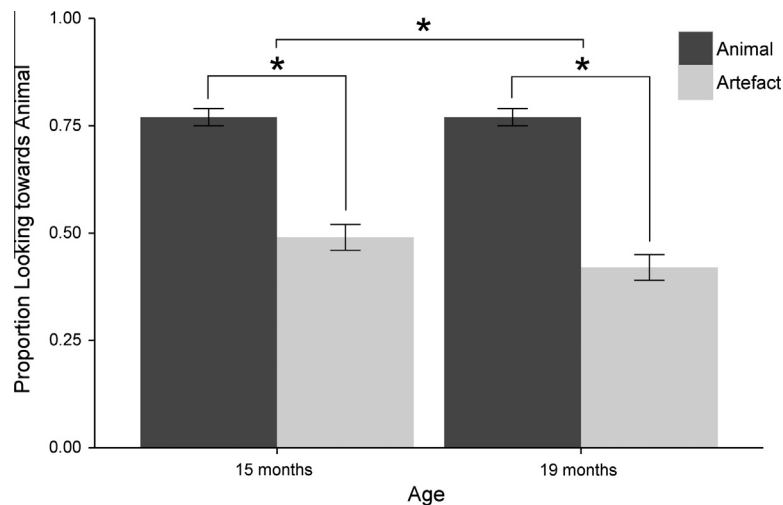


Fig. 2. Infants' performance on familiar trials. Both age groups oriented their looking based on the known word heard during the dialogue and test phases.

to the named target; attention to the animal and artefact diverged by 500 ms after the onset of the target word.

On unfamiliar trials, infants also revealed an overall preference for the animal ($M_{19\text{-months}} = .60$, $M_{15\text{-months}} = .55$). However, only at 19 months was their looking moderated by condition, $\beta_{\text{Age} \times \text{Condition}} = .14$, $SE = .07$, $\chi^2(1) = 3.74$, $p = .05$. As can be seen in Fig. 4, 19-month-olds looked significantly more towards the animal in the Informative ($M = .64$, $SD = .12$) than the Neutral condition ($M = .56$, $SD = .08$), $\beta = .10$, $SE = .05$, $\chi^2(1) = 4.23$, $p = .04$. At 15 months, infants performed comparably in the Informative ($M = .53$, $SD = .18$) and Neutral ($M = .57$, $SD = .07$) conditions ($\beta = -.04$, $SE = .06$, $\chi^2(1) = .52$, $p = .48$). An analysis of the timecourse data (Fig. 5) revealed that at 19 (but

not 15) months, infants systematically, but slowly, deployed their attention differently in the Informative and Neutral conditions. Notice that although this divergence occurred later on unfamiliar than familiar test trials, the results nonetheless reveal that 19-month-olds successfully recruit their representations of familiar verbs to identify the referent of novel nouns that occurs later as their arguments.

In a series of subsequent analyses, we asked whether performance at either age could be predicted by either infants' total productive vocabulary or their comprehension of the particular verbs we introduced (measured by parental report). There was no evidence that this was the case.

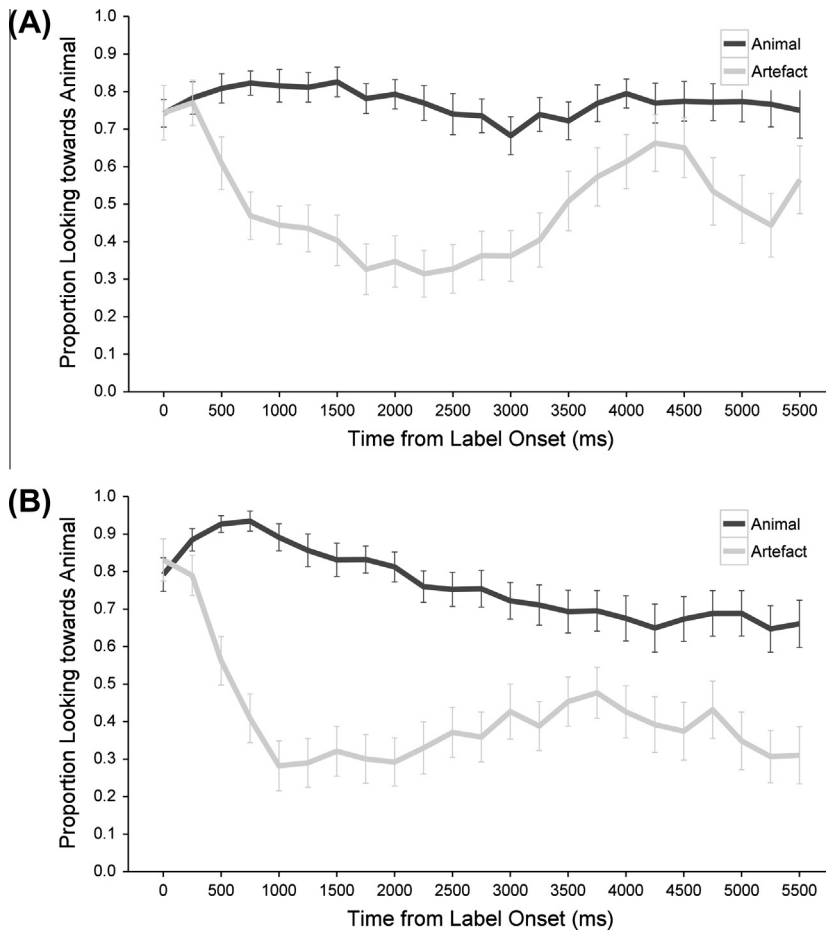


Fig. 3. Timecourse of familiar trials for 15-month-olds (A) and 19-month-olds (B). Both age groups' looking rapidly diverged depending on whether the animal or artefact was named. This divergence occurred from 500 to 4250 ms for the 15-month-olds ($p < .04$ all bins) and from 500 to 5500 ms for the 19-month-olds ($p < .02$ all bins).

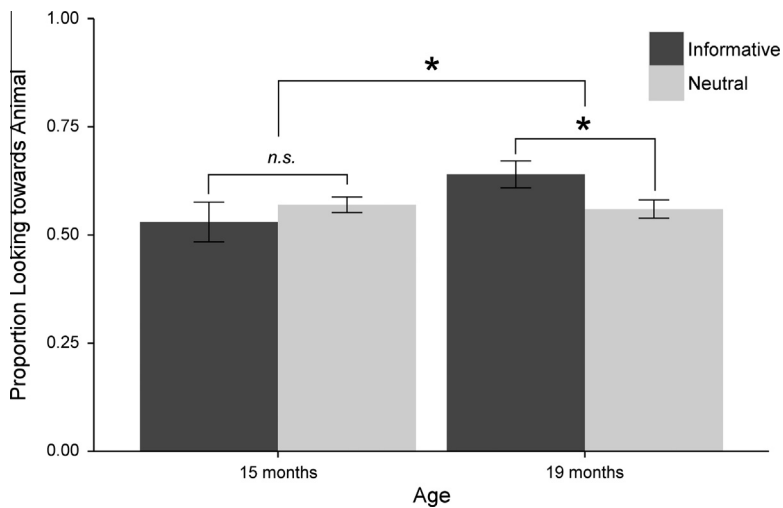


Fig. 4. Infants' performance on unfamiliar trials. Performance differed by age; 19-month-olds showed a significant effect of condition (Informative versus Neutral) while 15-month-olds showed no such difference.

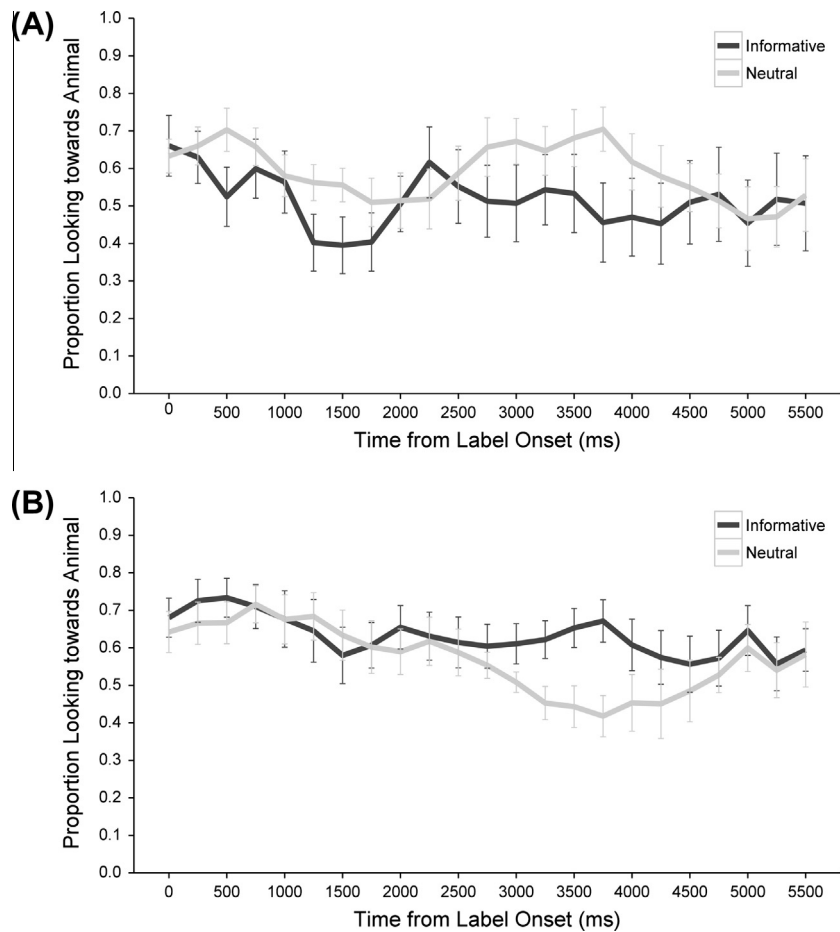


Fig. 5. Timecourse of unfamiliar trials for 15-month-olds (A) and 19-month-olds (B). Although at 15 months, performance in the two conditions appears to diverge, it does so only slightly and only within a single bin (3750–4000 ms; $p = .05$); its brevity and its direction (opposite to the predictions) suggest that this is spurious. At 19 months, looking diverged consistently by condition from 3250 to 4000 ms post-word onset ($p < .02$ all bins).

5. Discussion

By 19 months, infants successfully recruit their modest verb knowledge to identify the referents of novel nouns that appear as their subjects. Remarkably, 19-month-old infants' representation of the verb itself – without any cues from the visual scene – is sufficiently robust to be recruited downstream to guide their identification of a referent of a novel noun. This capacity is not yet evident in younger infants. Although 15-month-olds understood most of the verbs we introduced and successfully identified the referents of familiar nouns in this paradigm, they did not use known verbs to identify referents of novel nouns.

This work offers insight into developmental processes underlying the acquisition of verb meaning that have remained hidden in more traditional comprehension and production measures. Analyses of comprehension and production revealed a developmental *décalage*: Although infants comprehend at least some verbs by 10 months (Bergelson & Swingley, 2013), they do not produce these until much later (Goldin-Meadow, Seligman, & Gelman, 1976; Naigles et al., 2009; Tomasello, 1992). This *décalage*, often attributed to the different demands underlying

comprehension and production, has left open fundamental questions concerning the representational status of infants' early verbs (e.g., Fisher, 2002; Forbes & Poulin-Dubois, 1997; Gentner, 1978; Maguire, Hirsh-Pasek, & Golinkoff, 2006; Naigles, 2002; Tomasello, 1992). The current paradigm sheds light on these questions by documenting infants' advances in recruiting their modest stock of verbs to learn new nouns during this very active developmental period.

Armed with this new evidence, how can we best account for the developmental difference between 15- and 19-month-olds? We consider two broad possibilities. First, this may reflect differences in infants' representations of familiar verbs like *kiss* and *drink*. Although 15-month-olds may successfully recognize candidate referents of these verbs, perhaps their representations do not yet include selectional information (e.g., that the subject of a given verb must be animate). This interpretation is consistent with evidence that only by 19 months do infants begin to integrate selectional restrictions in sentence comprehension (Friedrich & Friederici, 2005), and that, within this same developmental period, infants begin to extend known verbs to scenes involving new participants in both

production (Naigles et al., 2009; Tomasello, 1992) and comprehension (Forbes & Poulin-Dubois, 1997; Meints, Plunkett, & Harris, 2008). A key question for future work will be to specify more precisely what information is included in infants' earliest verb representations and to identify how this information is enriched between their earliest moments of verb recognition and their first demonstrations of flexibility in verb production.

A second possibility, and one that is not mutually exclusive to the first, is that 15-month-olds' limitation is not in their representations of the familiar verbs *per se*, but in their processing capacities. Our task is cognitively demanding: Infants must access their representations of familiar verbs quickly and at the same time as they encode a novel word form. Recall that on familiar trials, infants at both ages rapidly oriented towards the referents of the familiar nouns (<500 ms), but that on unfamiliar trials, even 19-month-olds showed a processing lag: Although 19-month-olds in the Informative condition did eventually orient more toward the referent of the novel noun than infants in the Neutral condition, this took much longer (at 3250 ms) than on the familiar trials. It is therefore plausible that 15-month-olds had robust representations of the verbs we introduced, and that their representations included selectional information, but that they were unable to access these representations with sufficient speed. This interpretation is consistent with evidence that, as infants approach their second birthday, their speed and efficiency in both sentence processing and word comprehension increases (Fernald et al., 2008; Lew-Williams & Fernald, 2007). A goal for future work will be to specify more precisely the processing burden imposed and to ascertain whether reducing this burden (e.g., by familiarizing infants with the known verbs prior to the task) might permit younger infants to succeed.

For infants, identifying the meaning of new word is a challenge. Here, we have documented that infants recruit what they do know about language to meet this challenge. A goal for future work will be to specify the nature of their linguistic representations and processes that underlie this ability.

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Appendix A.

Familiar Trial – Example script

Woman: The bottle is right here.

Man: Really? The bottle is right here?

W: Yes! Let's find the bottle!

(Other neutral predicates: *so close, so wet, so little, nearby, very clean*)

Unfamiliar Trial (Informative) – Example script

Woman: The blick is crying.

Man: Really? The blick is crying?

W: Yes! Let's find the blick!

Unfamiliar Trial (Neutral) – Example script

Woman: The biff is right here.

Man: Really? The biff is right here?

W: Yes! Let's find the biff!

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