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Counting the Nouns: Simple Structural Cues to Verb Meaning

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Two-year-olds use the sentence structures verbs appear in—*subcategorization frames*—to guide verb learning. This is syntactic bootstrapping. This study probed the developmental origins of this ability. The structure-mapping account proposes that children begin with a bias toward one-to-one mapping between nouns in sentences and participant roles in events. This account predicts that subcategorization frames should guide very early verb learning, if the number of nouns in the sentences is informative. In 3 experiments, one hundred and thirty-six 21- and 19-month-olds assigned appropriately different interpretations to novel verbs in transitive (''He's gorping him!'') versus intransitive sentences (''He's gorping!'') differing in their number of nouns. Thus, subcategorization frames guide verb interpretation in very young children. These findings constrain theoretical proposals about mechanisms for syntactic bootstrapping.

Verbs differ in the syntactic structures they occur in, and these differences reflect aspects of their meanings. Part of each verb's meaning is a semantic predicate-argument structure specifying how many participant roles the verb involves. This semantic structure partly determines which syntactic structures the verb accepts, known as its *subcategorization frames*. To illustrate, verbs involving one participant role take intransitive frames, with one noun-phrase (NP) argument (*She fell*; *She laughed*); in contrast, verbs involving two participant roles take transitive frames, with two NP arguments (*She pushed her; She tickled her*). Such relations are strikingly similar across languages (e.g., Grimshaw, 1990; Levin & Rappaport Hovav, 2005; Pinker, 1989).

Children use subcategorization frames to interpret verbs; this is syntactic bootstrapping (e.g., Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005). For example, 25-month-olds who heard a made-up verb in a transitive frame (''The duck is gorping the bunny!'') looked longer at an event in which a duck acted on a bunny than at one in which the duck and bunny acted independently; those who heard the verb in an intransitive frame (''The duck and the bunny are gorping!'') did not (Naigles, 1990).

Here, we explore the developmental origins of syntactic bootstrapping. There is as yet little evidence for the use of subcategorization frames to guide verb learning by children under 2 years old. In tasks like the one just described, children under age 2 failed to assign appropriately different interpretations to verbs presented in transitive and intransitive sentences (Bavin & Growcott, 2000; Hirsh-Pasek, Golinkoff, & Naigles, 1996; Naigles & Swensen, 2007). These negative findings raise two related questions about the development of syntactic bootstrapping: First, when in development do children begin to use subcategorization frames to guide verb learning? And second, by what mechanisms do they develop the ability to do so?

The Origins of Syntactic Bootstrapping

Syntactic bootstrapping requires that children possess links between syntax and semantics that permit them to infer aspects of verb meaning from subcategorization frames. The developmental

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origins of such links are controversial. Below, we sketch our *structure-mapping* account of the origins of syntactic bootstrapping (e.g., Fisher, 1996; Lidz, Gleitman, & Gleitman, 2003), and contrast it with a *lexical* account of syntax acquisition (e.g., Abbot-Smith, Lieven, & Tomasello, 2008; Tomasello, 2003). These accounts posit different mechanisms for children's initial knowledge of syntax–semantics links and therefore make different predictions regarding when in development children gain access to these links. The structure-mapping account strongly predicts sensitivity to simple subcategorization frames in the 2nd year of life, whereas the lexical account does not. Explorations of the developmental time course of syntactic bootstrapping can therefore help to constrain our choices among these broad theoretical options.

Structure mapping. We and others have proposed a structure-mapping account of the origins of syntactic bootstrapping (e.g., Fisher, 1996; Fisher, Gertner, Scott, & Yuan, 2010; Lidz et al., 2003). Inspired by Gentner's (1983) structure-mapping view of analogy, our account proposes that children learn aspects of a verb's meaning by aligning a structured representation of an input sentence with a structured conceptual representation of an event. The key assumption is that syntactic bootstrapping begins with an unlearned bias toward one-to-one mapping between nouns in sentences and participant roles in conceptual representations. Given this bias, the number of nouns in a sentence is inherently meaningful: Even a young child can infer that a verb combined with two nouns implies two participant roles, whereas a verb combined with one noun implies one participant role. Such inferences yield a probabilistic distinction between the transitive and intransitive subcategorization frames. The structure-mapping account centrally assumes that learners are constrained to represent sentences and their possible interpretations in a usefully abstract format. Therefore, children represent diverse sentences in terms of their number of nouns, and diverse events in terms of their number of core participants. These abstract representations, and the similarity in their structures, give children access to an innate bias to align nouns with participant roles.

To illustrate, suppose a toddler hears an unknown verb combined with two known nouns (e.g., ''She's gorping her!'') in the context of the scene shown in Figure 1a. This scene could give rise to a set of conceptual representations: One person is feeding another, who is eating, and also sitting, for example. On the structure-mapping account, very young children could use the structure of this sentence to choose among these conceptual representations as follows: Even before children know enough about their native language to build a complete syntactic structure for the sentence, they can build a partial sentence representation identifying the sentence as containing an unknown verb and two nouns (e.g., Fisher, Hall, Rakowitz, & Gleitman, 1994). Armed with the proposed one-to-one mapping bias, children could map this two-noun sentence onto a conceptual representation involving two participant roles (perhaps FEEDING). As a result of detecting a structural match between sentence and scene representations, children could find simple aspects of sentence structure intrinsically meaningful.

This account makes a strong prediction: The number of nouns in a sentence should guide very early verb learning. Via structure mapping, the semantic significance of transitivity does not depend on prior verb learning or on much prior learning about the native-language syntax. As soon as children can identify some nouns and represent them as parts of a larger sentence structure, they should assign different interpretations to transitive and intransitive verbs, essentially by counting the nouns. Children under 2 years old appear to satisfy these prerequisites. First, nouns dominate in early vocabularies, suggesting that noun learning precedes and scaffolds the learning of other aspects of the vocabulary and grammar (e.g., Caselli et al., 1995; Gentner, 1982; Golinkoff & Hirsh-Pasek, 2008; Snedeker, Geren, & Shafto, 2007). Second, 18-month-olds and even younger infants understand multiword sentences under some circumstances, suggesting that they can represent multiple words per sentence, and integrate them in interpreting the sentence (Gertner, Fisher, & Eisengart, 2006; Hirsh-Pasek & Golinkoff, 1996; Seidl, Hollich, & Jusczyk, 2003). The structure-mapping account therefore must predict that children under 2 years old should use subcategorization frames to interpret transitive and intransitive verbs differently.

If so, why did children under 2 years old fail in prior syntactic-bootstrapping experiments? These failures could have resulted from the linguistic complexity of the stimulus sentences. The previous experiments compared transitive and intransitive sentences when both contained two nouns, as in Sentences 1 and 2 (Bavin & Growcott, 2000; Hirsh-Pasek et al., 1996; Naigles & Swensen, 2007).

1. *Transitive*: The duck is gorping the bunny.

2. *Intransitive*: The duck and the bunny are gorping.

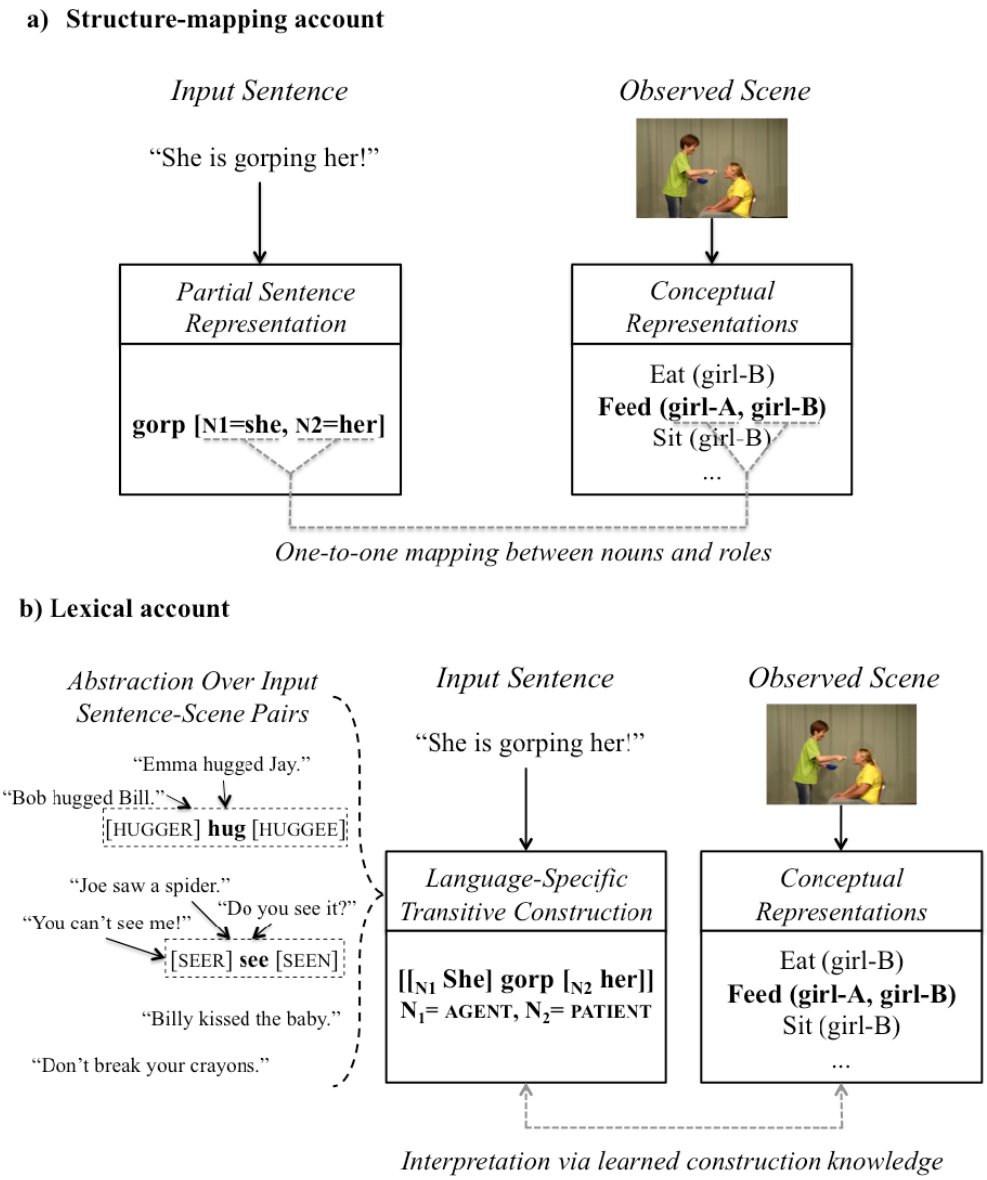


Figure 1. Schematic diagrams of the origins of syntactic bootstrapping via the structure-mapping and lexical accounts.
Note. On the structure-mapping account (a), children are innately biased to align nouns in sentences one-to-one with core participant roles in events. No language-specific syntactic learning beyond the ability to identify some nouns is required to permit this early form of syntactic bootstrapping. In contrast, on the lexical account (b), children are equipped with no innate links between sentence structure and meaning. Thus, in order to use sentence structure to guide verb interpretation, children must first discover language-specific constructions via a gradual process of abstraction over sentence–scene pairs in the input, sketched in the left panel of Figure 1b.

To identify Sentence 2 as intransitive despite the presence of two nouns, children must already have learned the language-specific features identifying this complex sentence structure, such as the conjunction *and*, the plural-marked auxiliary *are*, and the fact that noun-noun-verb is not the canonical order for English transitive sentences. Predictions about when in development children can tell apart Sentences 1 and 2 therefore depend on their command of these language-specific facts, in addition to their sensitivity to the semantic significance of transitivity. Given the proposed bias toward one-to-one mapping, however, structure mapping predicts early success in distinguishing transitive from intransitive verbs *if the sentences are simplified so that the number of nouns in the sentence is informative*.

In sum, the structure-mapping account requires that toddlers represent sentences and their possible

meanings in an abstract format and that these representations guide interpretation via simple innate constraints on links between sentence structure and meaning (i.e., the proposed one-to-one mapping bias). Both of these assumptions are controversial, as we will see next in our description of a lexical account of syntax acquisition.

Lexical account. Lexical or usage-based accounts of syntax acquisition propose that early representations of sentence structure and meaning are concrete and word specific and that children approach language learning without innate constraints on possible relations between syntax and meaning (e.g., Tomasello, 2003). Thus, on the lexical account, young learners would not have access to the one-to-one mapping procedure shown in Figure 1a. Instead, syntactic bootstrapping must await the gradual emergence of a language-specific syntactic–semantic *construction* corresponding to each subcategorization frame. Such constructions are formed by comparison across many memorized sentence–scene exemplars (e.g., Abbot-Smith et al., 2008).

Figure 1b illustrates how this might work. Upon hearing ''She's gorping her,'' children should be unable to use this sentence's structure to guide its interpretation until they have acquired a language-specific transitive construction abstract enough to apply to a sentence containing a novel verb. This construction might specify that English transitive sentences have the structure noun-verb-noun, and that the two nouns name participants who play particular roles (i.e., agent and patient). On the lexical account, this construction emerges gradually from many previous input sentence–scene pairs; each of these sentences must be interpreted based on event context alone, without the aid of syntactic bootstrapping. The detection of similarities across these input pairs in both sentence form and meaning leads to increasingly abstract knowledge. For example, children might first note that a word naming the ''hugger'' precedes the verb *hug*, and another word naming the ''huggee'' follows this verb. Next, by detecting similarities among a growing set of such lexicalized constructions (e.g., involving seers and things seen, kissers and kissees), children might note a much more general pattern: that nouns naming agents precede transitive verbs, and nouns naming patients follow them. On a lexical account, the abstract syntactic and semantic notions required to state such a generalization (including noun, transitive verb, agent, patient, subject, and object) emerge via comparison over input sentences and scenes, without the aid of innate linguistic constraints. Finally, once children have built a representation of the English transitive construction that reflects these abstract relations between form and meaning, they can use that construction to guide verb learning.

How quickly should an abstract transitive construction emerge? A challenge for theories of this kind is to explain how abstract syntactic and semantic notions emerge via comparison, and what conceptual precursors allow them to be constructed. Detailed predictions about the rate of development depend on answers to these questions. On the lexical account, the learner's search for patterns is assumed to be quite unconstrained; therefore, verb-general constructions are slow to emerge because the features of sentence form and meaning needed to detect such general patterns must be disentangled from a host of irrelevant features. As a result, early language use is dominated by less abstract item-specific representations, such as those sketched in the left-hand panel of Figure 1b. The robust creation of a verb-general transitive construction is typically predicted to be delayed until beyond the second birthday, and this delay has been used to account for phenomena such as young children's unwillingness to productively extend verbs to new sentence frames in both comprehension and production tasks (e.g., Tomasello, 2003).

According to the lexical account, the lack of evidence for sensitivity to subcategorization frames in toddlers is exactly what one would expect: Children under age 2 are unlikely to have built abstract representations that would allow them to systematically discriminate novel transitive versus intransitive verbs, and to assign to them appropriately different interpretations.

The Present Research

The present research tested the predictions of the structure-mapping account by seeking evidence of sensitivity to the semantic significance of transitivity in children under 2 years old. We asked whether 21- (Experiments 1 and 2) and 19-month-olds (Experiment 3) can use a novel verb's subcategorization frame (transitive vs. intransitive) to guide its interpretation, when the stimulus sentences are simplified to make the number of nouns informative.

In Experiment 1, 21-month-olds saw two simultaneous events: a two-participant caused-motion event (one man causing another to bend forward and back by pushing and pulling on his shoulders; Figure 2), and a one-participant action event (a man making arm motions). These events were accompanied by a novel verb in *transitive* (''He's gorping him!'') or *intransitive* (''He's gorping!'') sentences,

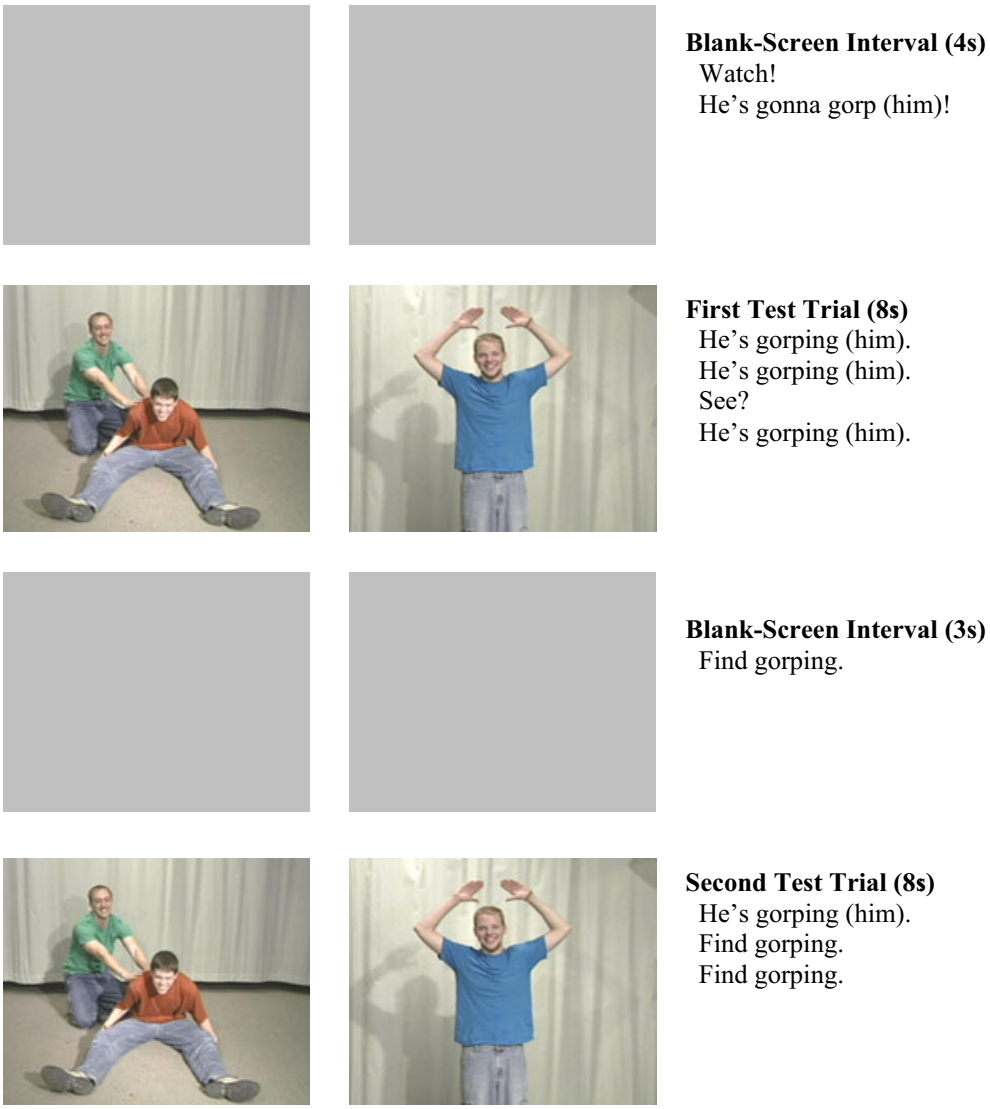


Figure 2. Sequence of events in the novel-verb item of Experiment 1 (21-month-olds).
Note. In the two-participant event, one actor causes the other to bend forward and back by pushing and pulling on his shoulder. In the one-participant event, the actor makes arm motions as in jumping jacks. The accompanying soundtrack shows both the transitive and intransitive sentence conditions: These two conditions differ only in the presence or absence of the pronoun in parentheses.

or by *neutral* audio with no novel verb (e.g., ''That looks fun!'') to assess baseline preferences. The use of ambiguous pronouns ensured that the two key sentence conditions differed in their number of NPs, but not in the semantic content of these NPs (see also Fisher, 2002). Both pronouns had the same semantic content, specifying a male referent; the key difference lay in whether the sentence as a whole mentioned two or one participants.

If 21-month-olds are sensitive to the semantic significance of transitivity, they should assign different interpretations to transitive and intransitive verbs in this task. Children in the transitive condition should note that their test sentence contained two nouns, and infer that the verb's meaning involved two participant roles. They should therefore look longer at the two-participant event than would children in the intransitive and neutral conditions. Children in the intransitive condition should note that their test sentence contained one noun, and infer that the verb's meaning involved one participant role. Note that this intransitive verb could refer either to the one-participant action event or to a component of the two-participant caused-motion event (Fernandes, Marcus, Di Nubila, & Vouloumanos, 2006; Fisher, 2002). Thus, we predicted no systematic preference for either event in the intransitive condition, relative to the neutral condition.

Experiment 1

Method

Participants. Twenty-four native English-speaking 21-month-olds (12 girls, 12 boys; M_{age} = 21.3 months, range = 19.8–23.5) participated, 8 in each of three conditions (transitive, intransitive, neutral). One additional child was excluded due to inattentiveness (looking at the test events for < 70% of the time during the novel-verb test item; see the Procedure section below). The median productive vocabulary, measured using the short form of the MacArthur–Bates Communicative Development Inventory (CDI) Level II (Fenson et al., 2000), was 30 (range = 0–82). The participants in this and the following experiments were predominantly from White and middle-class families. Families were recruited through a subject file based on birth announcements in a local newspaper, purchased mailing lists, and referrals from families who came in to participate.

Apparatus. Children sat on a parent's lap in a dimly lit room, facing two 20-in. color TV screens 12 in. apart, about 30 in. away. Audio stimuli played from a central speaker. A hidden central camera recorded children's eye movements. Parents wore opaque sunglasses.

Materials. The children watched a synchronized pair of videos showing people performing simple actions. The soundtracks were recorded by a female native English speaker.

Procedure. The procedure included three items: two practice items involving familiar verbs (one intransitive, *clap*; one transitive, *tickle*), and one novel-verb test item (*gorp*). Each item included two 8-s trials in which a pair of video events was presented.

The procedure began with the first practice item, involving the familiar intransitive verb *clap*. First, a sentence containing the verb was presented during a 4-s blank-screen interval (''He's gonna clap!''). Next, two 8-s video events played simultaneously, one on each screen, while children heard the stimulus sentence (''He's clapping!'') three times. The target event showed a man clapping; the distracter event showed a different man sleeping. During a 3-s blank-screen interval, children heard ''Find clapping!'' The two 8-s video events then played again while children heard ''He's clapping. Find clapping! Find clapping!'' Thus, the verb *clap* was presented in five intransitive sentences and three prompts to ''Find clapping.''

This procedure was repeated with the second practice verb, the familiar transitive verb *tickle*. Children heard *tickle* in five transitive sentences (''She's tickling her!'') and three prompts (''Find tickling!''). The target event showed one woman tickling another, and the distracter event showed one woman feeding another. The practice items showed children that one of the two events matched the soundtrack on each trial. To highlight this correspondence, we made the target event in the first item (clapping) much more interesting than the distracter (the ''sleeping'' actor hardly moved). The side of target video presentation differed across practice items.

Finally, in the test item, the novel verb *gorp* was presented in the same way described for the practice items. Figure 2 shows the two novel events. Depending on condition, children heard the verb in five transitive (''He's gorping him!'') or five intransitive (''He's gorping!'') sentences and in three prompts (''Find gorping!''), or they heard neutral sentences that did not contain a novel verb (e.g., ''Watch this!'').

In both practice and test items, actor gender matched in paired events, so children could not use pronoun gender to find the target event. Each actor appeared in only one event. The left–right side of event presentation was counterbalanced with sentence condition.

Coding. We coded where children looked (left, right, away) during the two 8-s test trials, frame by frame from silent video. In this and the following experiments, coding reliability was assessed for 25% of the participants; independent coders agreed on 98% of coded video frames.

Preliminary analyses of time spent looking away (in seconds, averaged across the two 8-s test trials) revealed no effect of sentence condition ($F < 1$), suggesting that children in all conditions tended to look away about equally (transitive: M = 0.31 s, SD = 0.56; intransitive: M = 0.51 s, SD = 0.60; neutral: M = 0.55 s, SD = 0.48). Given the uniformity of look-away times across conditions, we analyzed a single measure: Looking time to the two-participant event, as a proportion of looking time to either test event, averaged across the two 8-s test trials.

Preliminary analyses of the test data in this and the following experiments revealed no interactions involving sentence condition and gender, whether children's target preference in the practice trials was above or below the median, or whether children's productive vocabulary was above or below the median. The data were therefore collapsed over these factors.

Results

As Figure 3a shows, the 21-month-olds' looking preferences varied as predicted with sentence

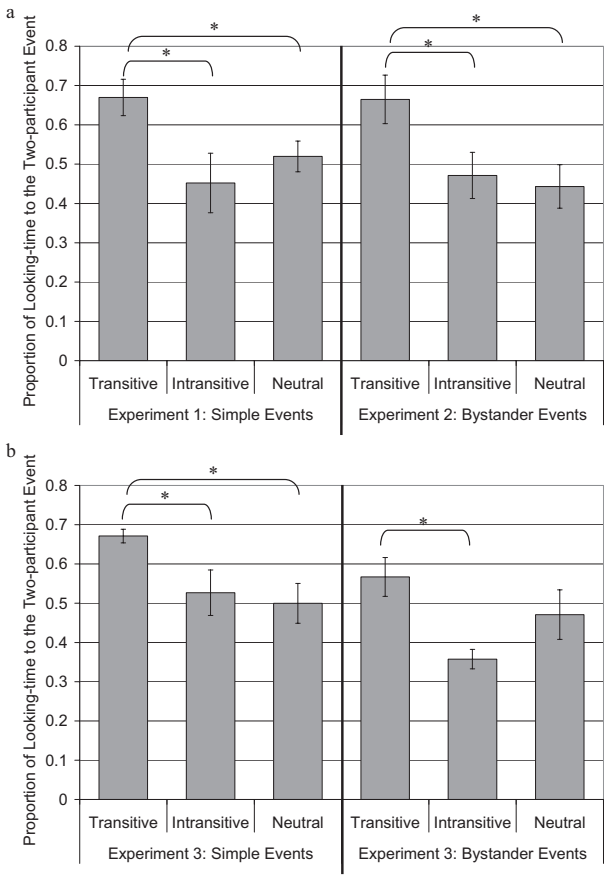


Figure 3. Mean proportion (*se*) of looking time to the two-participant event out of the total time spent looking at either test event, averaged across trials of the test item, for Experiments 1 and 2 (a, 21-month-olds) and Experiment 3 (b, 19-month-olds). *$p < .05$.

condition. Children who heard transitive sentences looked longer at the two-participant event than did those who heard intransitive sentences, or who heard neutral audio. An analysis of variance (ANOVA) revealed a significant effect of sentence condition, $F(2, 21) = 3.96$, $p = .035$, on the proportion of looking time to the two-participant event. Planned comparisons revealed that children in the transitive condition ($M = .67$, $SD = .13$) looked reliably longer at the 2-participant event than did those in the intransitive ($M = .45$, $SD = .21$), $t(14) = 2.45$, $p = .028$, $d = 1.31$, or neutral conditions ($M = .52$, $SD = .11$), $t(14) = 2.47$, $p = .027$, $d = 1.32$. The intransitive and neutral conditions did not differ, $t(14) < 1$, $p = .44$.

Replication. To confirm the key effect of transitivity, 16 additional 21-month-olds (8 girls, 8 boys; $M_{age} = 21.3$ months, range = 19.9–22.4) were tested in the transitive and intransitive conditions in another laboratory (in Cambridge, MA). Their median productive vocabulary was 54.5 (12–93). The procedure and materials were identical to those described above except that: (a) the synchronized video events were projected onto one large screen, (b) the novel verb was *stipe*, (c) a different pair of events was presented in the novel-verb test item (Figure 4a), and (d) the novel-verb sentences contained feminine rather than masculine pronouns, appropriate for these events. Preliminary analyses again revealed no effect of sentence condition on raw look-away times in the test item (transitive: $M = 0.21$ s, $SD = 0.25$; intransitive: $M = 0.31$ s, $SD = 0.65$; $t < 1$); thus, we again treated the proportion of time spent looking at the two-participant event as our dependent measure. These data confirmed the key result of the main experiment: Children in the transitive condition ($M = .70$, $SD = .16$) looked reliably longer at the two-participant event than did those in the intransitive condition ($M = .49$, $SD = .13$), $t(14) = 2.86$, $p = .013$, $d = 1.53$.

Discussion

The findings of Experiment 1 and its replication revealed clear sensitivity to the semantic significance of transitive versus intransitive subcategorization frames at 21 months. When the sentences were simplified such that the number of nouns was informative, transitivity strongly influenced 21-month-olds' interpretation of a novel verb. Those who heard the verb in transitive sentences (''He's gorping him!'') looked longer at the two-participant event than did those who heard it in intransitive sentences (''He's gorping!''), or who heard neutral audio. As expected, children in the intransitive condition showed no preference for either event relative to the neutral baseline, suggesting that they readily interpreted an intransitive verb as referring either to the one-participant event or to a component of the two-participant event. The striking difference between transitive and intransitive conditions shows that 21-month-olds are sensitive to the semantic significance of transitivity, at least in these simple sentences. A transitive (two-noun) verb refers to an event with two participant roles, whereas an intransitive (one-noun) verb need not.

Experiment 2

The early sensitivity to transitivity documented in Experiment 1 is consistent with the structure-mapping account, which holds that toddlers are biased to seek a one-to-one mapping between nouns in sentences and participant roles in events. An

Figure 4. The pair of novel events for the novel-verb test item (a) in the replication of Experiment 1 (21-month-olds), and (b) in Experiment 2 (21-month-olds) and Experiment 3 (19-month-olds, bystander-events condition).

alternative interpretation, however, is that the 21-month-olds in Experiment 1 did something much simpler. Perhaps they simply matched the number of nouns in the sentence to the number of people on each TV screen rather than to the number of participant roles in each event. In Experiment 2, we sought both to replicate the findings of Experiment 1 and to rule out this alternative interpretation.

To do so, in Experiment 2, we introduced a second person (a ''bystander'') into the one-participant action event presented in the novel-verb test item. One test event again showed a two-participant caused-motion event: One woman rotated another on a tall swivel chair (Figure 4b). The other was the bystander event: One woman bounced on a yoga ball, whereas another stood idly by. Both test events thus showed two people but differed in whether both people filled participant roles in a coherent event. Even prelinguistic infants differentiate objects that are merely present from objects that are core participants in a coherent event (e.g., Gordon, 2004). Children again heard a novel verb in transitive (''She's flomming her!'') or intransitive (''She's flomming!'') sentences, or heard neutral audio (e.g., ''Watch this!'').

If children succeeded in Experiment 1 simply by aligning nouns with people, then in Experiment 2 we should find no differences across conditions. Children who heard transitive sentences containing two nouns should not systematically prefer either event because both depicted two people. Children who heard intransitive sentences containing one noun should again show no clear preference between the events because both depicted at least one person. In contrast, if children succeeded in Experiment 1 by aligning nouns with participant roles in coherent event representations, then Experiment 2 should reproduce the effects of Experiment 1: Children who heard transitive sentences should seek a coherent two-participant event and should therefore look longer at the two-participant event than children in the intransitive and neutral conditions.

Method

Participants. Twenty-four 21-month-olds (12 girls, 12 boys; M_{age} = 20.7 months, range = 20.0–21.9) participated, 8 in each condition (transitive, intransitive, neutral). Four additional children were eliminated due to side bias (1; looking only at one screen during the practice or novel-verb test item) or inattentiveness (3; in addition to the criterion from Experiment 1, children in Experiments 2 and 3 were eliminated for inattentiveness if they looked

at the screen for < 1 s during at least one of the 5-s previews of the novel-verb test item. (Experiment 1 did not have a preview phase.) The median productive vocabulary score, measured as before, was 26.5 (range = 8–85).

Materials and procedure. The materials and procedure of Experiment 2 were similar to those of Experiment 1 except for several changes related to the ''bystander'' manipulation. (a) In the test item, children saw the novel events in Figure 4b, a two-participant caused-motion event and an event involving a one-participant action and a bystander. The bystander simply stood idly, moving slightly from time to time without looking directly at the actor. The intent was to include two people but to avoid suggesting any coherent relationship between them. (b) The familiar-verb practice items involved the intransitive verb *jump* (the distracter event showed *sleeping*), and the transitive verb *hug* (the distracter event showed *feeding*). (c) To reduce the novelty of the bystander in the test item, we added a bystander to both the target and distracter events during the first practice item (*jump*). Thus, every event in the experiment showed two people. (d) Each item began with a preview phase in which each event for that item was presented alone for 5 s, accompanied by neutral audio (e.g., ''Look here!''). (e) Children heard two additional sentences in each practice or test item, appropriate for their condition, one added before and one between the two 8-s trials; the blank-screen intervals were lengthened to 6 s to accommodate these additions. Thus, in Experiment 2, children in the transitive and intransitive conditions heard each familiar or novel verb in seven full sentences and three prompts. The additional sentences were added to mitigate the potentially confusing presence of the bystanders in the video stimuli.

Coding. Coding was carried out as in Experiment 1. Average look-away times in the test item, in seconds, did not differ across conditions ($F < 1.1$; transitive: $M = 0.58$ s, $SD = 0.47$; intransitive: $M = 0.39$ s, $SD = 0.24$; neutral: $M = 0.36$ s, $SD = 0.26$).

Results

The 21-month-olds' looking preferences varied as predicted across sentence conditions (see Figure 3a). An ANOVA revealed a main effect of sentence condition, $F(2, 21) = 4.23$, $p = .029$. Planned comparisons confirmed that children in the transitive condition ($M = .66$, $SD = .18$) looked reliably longer at the two-participant event than did those in the intransitive ($M = .47$, $SD = .17$), $t(14) = 2.27$, $p = .039$, $d = 1.21$, and neutral ($M = .44$, $SD = .16$), $t(14) = 2.67$, $p = .018$, $d = 1.43$, conditions. The intransitive and neutral conditions did not differ, $t(14) < 1$.

Discussion

Experiment 2 replicated and extended the findings of Experiment 1. As predicted by the structure-mapping account, 21-month-olds showed sensitivity to the semantic significance of transitivity in simple sentences. Children who heard the novel verb in transitive sentences looked longer at the two-participant event than did children who heard either intransitive sentences or neutral audio. Experiment 2, with its bystander manipulation, further showed that children who heard the new verb in transitive sentences looked longer at the two-participant event, not merely because that event showed two people, one for each noun, but because it depicted a coherent two-participant relationship. This suggests that children mapped their representations of our simple sentences onto a structured conceptual representation, and assigned a relational meaning to the transitive but not the intransitive verb.

Experiment 3

In Experiment 3, we extended our investigation to younger children, 19-month-olds. The structure-mapping account predicts that children should distinguish transitive from intransitive verbs in simple sentences as soon as they can identify multiple nouns per sentence. As noted earlier, 18- and perhaps even 15-month-olds can integrate multiple familiar words in comprehending sentences (Hirsh-Pasek & Golinkoff, 1996; Seidl et al., 2003). Thus, the structure-mapping account predicts that even these younger children should be able to use verb subcategorization in verb interpretation, when the sentences are simplified so that the number of nouns is informative.

Experiment 3 crossed three sentence conditions (transitive, intransitive, neutral) with two event conditions (simple event, bystander event). The novel events in the simple-event condition were those presented in Experiment 1: a two-participant caused-motion event and a one-participant event. The novel events in the bystander-event condition were those presented in Experiment 2: a two-participant caused-motion event and a one-participant event with a bystander. As in Experiment 2, the bystander-event condition allowed us to eliminate the possibility that toddlers simply aligned the

nouns in sentences with people rather than participant roles.

Experiment 3 also addressed another alternative interpretation of our findings. Dittmar, Abbot-Smith, Lieven, and Tomasello (2008) argued that previous results showing evidence of early sensitivity to syntax (e.g., Gertner et al., 2006) might be attributed to within-experiment learning during practice items that were highly similar to the critical test items. A similar argument could apply to the findings of Experiments 1 and 2. For example, in Experiment 1, in the first practice item, children heard a familiar intransitive verb (''He's clapping'') and saw one-participant events; in the second practice item, children heard a familiar transitive verb (''She's tickling her'') and saw two-participant events. These practice trials may have implicitly set up a contrast between intransitive and transitive verbs, mapped onto one- and two-participant events, respectively. In principle, such practice items might have supported test-item performance by teaching or priming children to link nouns in sentences with participant roles in events, within the confines of this task. To eliminate this possibility, we modified the practice item in Experiment 3, making it much less similar to the test item: The sentences named objects that an actor was holding up (''She has a shoe!'' ''She has a hat!''). This change greatly reduced the relevance of practice-item learning to later test-item performance, while still demonstrating to children that only one screen matched the soundtrack on each trial.

Whereas the structure-mapping account predicts that 19-month-olds, like 21-month-olds, should be sensitive to verb transitivity in interpreting simple sentences, it does not predict that 19-month-olds should be as efficient as older children in sentence processing. Between 18 and 24 months of age, children become faster and more accurate at identifying words (e.g., Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998); such differences have consequences for sentence interpretation. Pilot work suggested that 19-month-olds did not succeed with the task parameters designed for 21-month-olds in Experiments 1 and 2. Therefore, we modified the task to ease the language-processing demands for younger children, by including more repetitions of the test sentences during the test item, and lengthening the intertrial intervals to give children more time to process the sentences (see the Procedure section). In addition, we added a monologue phase, at the start of the experiment, in which the children saw a woman talking on the phone, using the novel verb *gorp* in sentences. The monologue phase was intended to facilitate language processing during the test item by providing pre-exposure to the novel verb and its syntactic contexts. Similar pre-exposure phases have been shown to help 18-month-olds more accurately encode the sound patterns of novel words (Swingley, 2007) and to permit 2-year-olds to learn a new verb's subcategorization frame based on listening experience (Arunachalam & Waxman, 2010; Yuan & Fisher, 2009). No referent events were shown in the monologue phase, thus this phase gave children no chance to learn what the new verb meant.

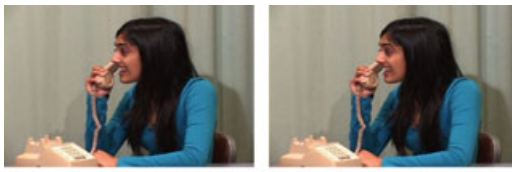
Method

Participants. Seventy-two 19-month-olds (36 girls, 36 boys; M_{age} = 18.8 months, range = 18.1–20.0) participated. Twelve were assigned to each sentence condition (transitive, intransitive, neutral) within each event condition (simple events, bystander events). Twenty additional children were eliminated due to fussiness (2), side bias (2; looking exclusively at one screen during the practice or novel-verb test item), inattentiveness (9), low practice-item performance (3; looking at the matching screen < 25% of the time), or test scores more than 3 *SD* from the condition mean (4). The median productive vocabulary score was 16 (range = 0–67). Parents reported that 35 children did ''not yet'' combine words in production, 25 did so ''sometimes,'' and 12 ''often.''

Materials and procedure. The procedure included a monologue phase, one practice item, and one novel-verb test item (*gorp*). Figure 5 illustrates the task, with test items from the simple-events condition.

In the monologue phase, children watched two four-sentence video clips (25–28 s), separated by a 2-s interval, showing a woman talking on the telephone, using the verb *gorp* in sentences. The same video appeared simultaneously on both TV screens. Children in the transitive condition heard eight transitive sentences (e.g., ''Michael is gonna gorp Grandpa!''), whereas those in the intransitive condition heard eight intransitive sentences (''Michael is gonna gorp!''); half of the children in the neutral condition heard each monologue. All nouns in the monologue had animate referents.

After a 7-s interval, a single practice item followed, involving the familiar verb *have*. Two 6-s video events were presented. One showed a woman holding a shoe; the other a woman holding a hat. The actors tilted the objects gently. Each



MONOLOGUE PHASE

Transitive Monologue	Intransitive Monologue
Hey, you know what?	Hey, you know what?
Michael is gonna gorp grandpa.	Michael is gonna gorp.
Yeah, he's gonna gorp grandpa.	Yeah, he's gonna gorp.
You know what else?	You know what else?
Abby was gorping the man.	Abby was gorping.
Yeah, she was gorping the man.	Yeah, she was gorping.
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Guess what?	Guess what?
Emma gorped the baby.	Emma gorped.
Yeah, she gorped the baby.	Yeah, she gorped.
You know what else?	You know what else?
Daniel was gorping the boy.	Daniel was gorping.
Yeah, he was gorping the boy.	Yeah, he was gorping.

PRACTICE PHASE

Who has a shoe / Who has a hat?

TEST PHASE

Transitive Condition
He's gorping him! He's gorping him!

Intransitive Condition
He's gorping! He's gorping!

Neutral Condition
What's happening? Look here!

Figure 5. Sequence of phases in the simple-events condition of Experiment 3 (19-month-olds).

event was previewed alone on one screen, in counterbalanced order, separated by a 3-s blank-screen interval, accompanied by audio labeling the object (e.g., ''She has a shoe!''). Next, during a 4-s blank-screen interval, children were prompted to look at the shoe event (''Who has a shoe?''). Both events then played simultaneously, while children heard ''Who has a shoe? She has a shoe.'' During another 4-s blank-screen interval, children were prompted to look at the hat event (''Who has a hat?''). The events were then presented again, while children heard ''Who has a hat? She has a hat.''

Following a 3-s blank-screen interval, the novel-verb test item was presented. In both event conditions, the novel events were shortened to 6 s to keep the task brief despite the addition of the monologue phase. Both novel events were previewed alone in counterbalanced order, separated by a 3-s blank-screen interval, accompanied by neutral audio (e.g., ''Watch this!''). Next, during an 8-s blank-screen interval, children heard a test sentence appropriate for their condition (e.g., ''He's gonna gorp (him)!'') twice. The novel events then played simultaneously, while children heard two more test sentences (e.g., ''He's gorping [him].'') Next, in a 6-s blank-screen interval, children heard another test sentence and a prompt (e.g., ''He gorped [him]. Find gorping!''). The novel events were then presented a second time, accompanied by one additional test sentence and a prompt. Finally, in the bystander-events condition only, children received a third test trial: They heard two more test sentences during another 6-s blank-screen interval, then heard two additional test sentences while both events played. Thus, children in the transitive and intransitive conditions heard the novel verb in 6 sentences and two prompts before and during two 6-s trials in the simple-events condition, and in 10 sentences and two prompts before and during three 6-s trials in the bystander-events condition. Pilot testing suggested that children in the bystander-events condition needed extra time to inspect the more complex stimulus events.

Coding. Coding was conducted as in Experiment 1. Individual test trials were dropped if the child looked away for more than 2 s of the 6-s trial ($n = 4$). Raw look-away times during the test trials did not vary with event or sentence condition (Fs < 1; simple-events condition: transitive $M = 0.51$ s, $SD = 0.30$, intransitive $M = 0.41$ s, $SD = 0.23$,

neutral $M = 0.40$ s, $SD = 0.24$; bystander-events condition: transitive $M = 0.45$ s, $SD = 0.33$, intransitive $M = 0.45$ s, $SD = 0.35$, neutral $M = 0.51$ s, $SD = 0.27$).

Results

As Figure 3b shows, 19-month-olds who heard the novel verb in transitive sentences looked longer at the two-participant event than did those who heard it in intransitive sentences or heard neutral audio. These effects were similar in the simple- and bystander-events conditions.

A 2 (event condition: simple events, bystander events) × 3 (sentence condition: transitive, intransitive, neutral) ANOVA revealed reliable main effects of event condition, $F(1, 66) = 6.86$, $p = .011$, and sentence condition, $F(2, 66) = 7.68$, $p = .001$. The main effect of event condition reflects a baseline tendency for children in the simple-events condition to look proportionately longer at the two-participant event ($M = .57$, $SD = .17$) than did children in the bystander-events condition ($M = .47$, $SD = .18$). There was no interaction of event and sentence condition, $F(2, 66) = 1.11$, suggesting that the effect of sentence condition was similar across event conditions. Planned comparisons showed that children in the transitive condition ($M = .62$, $SD = .14$) looked reliably longer at the two-participant event than did those in the intransitive ($M = .44$, $SD = .17$), $t(46) = 3.92$, $p < .001$, $d = 1.16$, or neutral conditions ($M = .49$, $SD = .19$), $t(46) = 2.76$, $p = .008$, $d = .81$. The intransitive and neutral conditions did not differ, $t(46) < 1$. A separate analysis of the data from the neutral condition revealed that looking preferences in this condition were unaffected by whether the children had heard the transitive ($M = .44$, $SD = .14$) or the intransitive monologues ($M = .54$, $SD = .23$), $t(22) = 1.28$, $p = .21$.

Follow-up analyses revealed similar findings within each event condition. The main effect of sentence condition held within each event condition: simple events, $F(2, 33) = 4.08$, $p = .026$, and bystander events, $F(2, 33) = 4.67$, $p = .016$. In the simple-events condition, children who heard transitive sentences ($M = .67$, $SD = .06$) looked longer at the two-participant event than did those who heard intransitive sentences ($M = .53$, $SD = .20$), $t(22) = 2.38$, $p = .026$, $d = 1.01$, or neutral audio ($M = .50$, $SD = .18$), $t(22) = 3.20$, $p = .004$, $d = 1.36$; the intransitive and neutral conditions did not differ, $t(22) < 1$. In the bystander-events condition, children in the transitive condition ($M = .57$, $SD = .17$) looked longer at the two-participant event than did those in the intransitive condition ($M = .36$, $SD = .09$), $t(22) = 3.78$, $p = .001$, $d = 1.61$; the looking preferences in the neutral condition ($M = .47$; $SD = .22$) did not differ significantly from either the transitive, $t(22) = 1.20$, $p = .24$, or the intransitive conditions, $t(22) = 1.67$, $p = .11$.

Discussion

Experiment 3 reproduced the key results of Experiments 1 and 2 with younger children, 19-month-olds. When the sentences were simplified so that the number of nouns was informative, 19-month-olds showed clear sensitivity to verb transitivity: They interpreted a novel transitive but not an intransitive verb as referring to a two-participant event. They did so even in the bystander-events condition, in which both novel events showed two people. This suggests that, like the 21-month-olds in Experiment 2, the 19-month-olds preferred to align each noun in the test sentences with a participant role in a coherent event.

The findings of Experiment 3 also suggest that toddlers' sensitivity to verb transitivity in our simple task did not depend on learning during practice items that were highly similar to the test items (cf. Dittmar et al., 2008). The practice item of Experiment 3 involved scenes and sentences that shared little similarity with the critical test item and therefore offered little opportunity to learn shallow sentence-interpretation strategies that could support test-item performance. Thus, the present results suggest that the 19-month-olds brought to the experiment some knowledge of the semantic significance of transitivity and that this knowledge was robust enough to influence their interpretation of a novel verb.

We cannot directly compare the performance of the 19-month-olds in Experiment 3 with that of the 21-month-olds in Experiments 1 and 2 because of the task modifications for the benefit of the younger children. The 19-month-olds received a monologue phase, heard more repetitions of the test sentences, and were given more time to inspect the events in the bystander-event condition than were the 21-month-olds. Thus, the positive results of Experiment 3 allow us to conclude that children as young as 19 months exhibit an underlying sensitivity to the number of nouns in sentences similar to that showed by older children, as long as they have the resources (time and language exposure) to cope with the sentences and the events. When these advantages are not available, younger children may use this sensitivity to interpret new verbs less

reliably than do older children, simply due to their lesser language-processing capacity.

In this supportive context, young children's sensitivity to the number of nouns did not appear to depend on their vocabulary size. In none of the experiments was vocabulary level strongly related to children's use of syntactic cues. As mentioned previously, we found no interaction of sentence condition and whether children's productive vocabulary was above or below the median in any of the experiments. In addition, in none of the experiments did we find a significant correlation between vocabulary size and the proportion of time spent looking at the two-participant event in the transitive condition (Experiment 1: $r = -.41$, $p = .12$, $n = 16$; Experiment 2: $r = .29$, $p = .49$, $n = 8$; Experiment 3: $r = .31$, $p = .14$, $n = 24$). As noted earlier, half of the 19-month-olds in Experiment 3 (35 of 70) had not yet started combining words in their speech, as assessed by parental report. These findings suggest that productive language development—including both vocabulary size and the onset of word combinations—is not a limiting factor in the ability to recruit simple sentence-structure cues to guide verb interpretation.

Thus, by 19 months, children can use a new verb's subcategorization frame to select a likely meaning for the verb from among multiple referential options. These findings complement recent evidence for the converse process in slightly younger infants. Brandone, Addy, Pulverman, Golinkoff, and Hirsh-Pasek (2006) habituated 17-month-olds to an event in which a woman raised and lowered her fist; balloons were fastened to the wall behind her. This event was labeled by a verb in isolation, in a discourse context making clear that the verb referred to the woman's action (''What's she doing? Tooping?''). The children looked longer during the subsequent test phase if they heard the verb in a transitive sentence (''She's tooping them!'') rather than in an intransitive sentence (''She's tooping!''). These and control results suggested that, by 17 months, infants expect a verb used to refer to a one-participant action to be intransitive. The present findings, and Brandone et al.'s results, depend on the same broad links between syntax and semantics (Gleitman, 1990; Pinker, 1989). When given evidence about a new verb's subcategorization frame, as in the present experiments, toddlers use syntax–semantics links to select the event the verb is likely to refer to. Conversely, when given scene evidence about a new verb's potential meaning, toddlers use semantics–syntax links to predict a likely subcategorization frame for the verb.

General Discussion

The present experiments yielded the first experimental evidence that children younger than age 2 use subcategorization frames to interpret verbs. Both 21- and 19-month-olds distinguished novel transitive from intransitive verbs, when the sentences were simplified so that the number of nouns was informative. Hearing a novel verb in two-noun transitive sentences (e.g., ''He's gorping him!'') guided their attention to a two-participant event, whereas hearing the verb in one-noun intransitive sentences (''He's gorping!) did not. Moreover, children's interpretation was constrained by their conceptual representations of the events. Both 21- and 19-month-olds interpreted a novel transitive verb as referring to a relational event with two core participant roles, not simply to a scene with two people. Thus, even very young children know something about the semantic significance of transitivity (see also Brandone et al., 2006). These results have implications for the two questions raised in the Introduction about the developmental time course of syntactic bootstrapping and its underlying mechanisms; each question is addressed in turn.

The Developmental Time Course of Syntactic Bootstrapping

The present results establish that children begin to use subcategorization frames to guide verb interpretation well before the second birthday. This implies that syntactic bootstrapping could play a substantial role in toddlers' sentence interpretation and verb learning.

Familiar properties of casual speech might seem to challenge the usefulness of subcategorization frames in early verb learning: Individual sentences can have missing arguments (e.g., ''Have a cookie''), or can contain more nouns than arguments (e.g., ''She saw the book on the table''). Thus, an individual sentence is not a reliable indicator of a verb's argument-taking privileges (e.g., Rispoli, 1995). However, we have argued that learners could overcome this difficulty in part by gathering syntactic information across sentences to estimate each verb's subcategorization properties (Fisher & Gleitman, 2002). Recent findings suggest that 2-year-olds have the necessary tools to do this (Yuan & Fisher, 2009): Twenty-nine-month-olds learned a new verb's subcategorization frames by hearing dialogues in which the verb was used in either transitive (''Anna blicked the baby!'') or intransitive sentences (''Anna blicked!''). When the children

later heard the same verb in a syntactically uninformative context (''Find blicking!''), they retrieved the subcategorization information they had encoded during the dialogues, and used it to interpret the verb (see also Arunachalam & Waxman, 2010; Scott & Fisher, 2009). Younger children, 23-month-olds, also succeeded in a version of this task (Yuan & Fisher, 2010). These abilities suggest that sensitivity to subcategorization frames could play a substantial role in early verb learning despite the unreliability of individual sentences: Toddlers, like adults, interpret a sentence using not only the syntactic information in the current sentence but also the verb's syntactic history.

Relatedly, the present results support our explanation of previous failures to document sensitivity to subcategorization frames in toddlers (Bavin & Growcott, 2000; Hirsh-Pasek et al., 1996; Naigles & Swensen, 2007). We argued that these failures might result from errors in identifying the true structure of stimulus sentences that contained more nouns than arguments (e.g., ''The duck and the bunny are kradding!''). In the present experiments, we simplified the sentences to make the number of nouns informative and found that 19- and 21-month-olds used transitive versus intransitive subcategorization frames to interpret verbs.

The contrast between toddlers' present success and the previous negative findings suggests that toddlers may often have difficulty in understanding complex sentences containing more nouns than arguments. For children and adults, the ease of sentence interpretation depends on many factors, including the comprehender's knowledge of the subcategorization of the verb (e.g., Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Snedeker & Trueswell, 2004), and the fit of candidate interpretations with the referential context (e.g., Clark, 1973; Huang & Snedeker, 2008; Knoeferle, Crocker, Scheepers, & Pickering, 2005; Shatz, 1978). If similar factors influence toddlers, then a young child hearing ''The duck and the bunny are kradding'' while viewing a caused-motion event (duck bends bunny) and a simultaneous-action event (duck and bunny both wheel their arms) is challenged on multiple grounds. First, the child has no prior evidence about the novel verb's subcategorization frame independent of this complex stimulus sentence. Second, one available event (the caused-motion event) provides a clear match for an incorrect but tempting interpretation of the sentence, one in which each noun maps onto a distinct participant role. The dialogue-and-test method introduced by Yuan and Fisher (2009) provides one possible route for lessening these difficulties, by separating the linguistic evidence from the referential options.

Should a partial sentence representation consisting of a set of nouns and an unknown word be considered a syntactic representation at all? We would argue that it is syntactic in that it reflects categories of words (nouns) represented as parts of a larger sentence. The main claim of the structure-mapping account is that sentence representations can guide comprehension before they reflect much language-specific morphosyntactic knowledge. Thus, in principle, toddlers who hear ''He's gorping him'' could infer that this sentence refers to a relationship between two participants as soon as they know that the words *he* and *him* have referential meanings and can represent them as parts of a larger sentence structure. This initial interpretation would not require robust knowledge of the language-specific morphosyntactic cues that would permit the child to identify unfamiliar nouns as nouns, or to determine whether the unknown word in the sentence is a verb or another predicate term such as an adjective (''He's happy for him'') or a preposition (''He's behind him''; Fisher, Klingler, & Song, 2006). However, it is possible that the toddlers in our experiments made use of sentence representations that reflected considerable knowledge about English nouns. By 14 months, children can use language-specific function-word cues to identify unfamiliar words as nouns, and interpret them accordingly (e.g., ''This is a blicket!''; Booth & Waxman, 2009). Future research will need to explore just how partial, versus how complete, the sentence representations of toddlers in the 2nd year of life might be.

Mechanisms for Syntactic Bootstrapping

What is the developmental origin of the syntax–semantics links that enabled the 19- and 21-month-olds in our experiments to infer aspects of verb meaning from subcategorization frames? Early sensitivity to subcategorization frames is just what we would expect if young children have access to the structure-mapping procedure. On this account, children are innately biased to align each noun in a sentence with a participant role in a conceptual representation of an event; as a result, they assign appropriately different interpretations to simple transitive versus intransitive sentences once they can identify some nouns in sentences. But a number of other questions remain that need to be addressed before we can interpret the present results as straightforward evidence for the structure-mapping

account. In what follows, we briefly discuss some of these questions.

Revisions to the lexical account. In principle, the lexical account could accommodate our findings by proposing that enough verbs have been learned by 19 months to establish language-specific knowledge of the relevant syntactic–semantic constructions. This possibility is difficult to evaluate, in part because it is hard to measure the verb vocabularies of young children, and in part because it is hard to tell how many verbs are needed for a lexical-account learner to build abstract constructions. Early productive vocabularies contain few verbs (e.g., Fenson et al., 1994; Golinkoff & Hirsh-Pasek, 2008), but comprehension studies suggest that infants between 12 and 18 months of age understand a number of action verbs, both transitive and intransitive (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Huttenlocher, Smiley, & Charney, 1983; Naigles & Hoff, 2006). Other things being equal, however, the earlier in development we find evidence that abstract sentence-structure knowledge guides sentence interpretation and verb learning, the harder it is for entirely unconstrained lexical learning to account for that evidence. Evidence for syntactic bootstrapping at 19 months is therefore a challenge to current lexical accounts of syntax acquisition.

Multiple cues to transitivity. One might propose that toddlers showed their sensitivity to subcategorization frames in our task in part because we provided additional prosodic or morphological markers of transitivity in our test sentences. For example, the novel verbs were sentence-final in the intransitive but not the transitive condition; as a result, the verbs were prosodically lengthened in the intransitive context relative to the transitive context. Such prosodic differences can serve as probabilistic cues to major grammatical categories (e.g., noun vs. verb), and adults and children use such cues in grammatical category assignment (e.g., Cassidy & Kelly, 1991; Conwell & Morgan, 2007). Similarly, the position of the verb itself (sentence-final vs. sentence-medial followed by a noun) could be a cue to verb transitivity. Our stimulus sentences also included case-marked pronouns—for example, ''He's gorping (him),'' ''She's stiping (her)''. Although case marking is limited in English, the distribution of these pronouns is syntactically constrained: *He* and *she* are subjects, and *him* and *her* tend not to be (although they can be subjects in sentences such as ''You saw *her crying*''). The use of these pronouns could have helped children in two ways. As high-frequency words with relatively predictable sentence positions, they should make it easier to process the stimulus sentences (e.g., Kedar, Casasola, & Lust, 2006; Swingley, 2007; Zangl & Fernald, 2007). In addition, the presence of an accusative case-marked pronoun (*him* or *her*) could serve as a probabilistic cue to transitivity, because these often appear in direct-object position (e.g., Ibbotson & Tomasello, 2009).

Could the present findings be explained by toddlers' sensitivity to prosodic or morphological cues to verb transitivity, in addition to, or instead of, the number of nouns in the sentence? There are several reasons to think that the number of nouns played a substantial role in our toddlers' ability to distinguish between transitive and intransitive verbs in the present experiments.

First, one prior syntactic bootstrapping study controlled for prosodic differences between sentence conditions and found evidence for sensitivity to the set of nouns (Fisher et al., 2006). Two-year-olds who heard a new word followed by a familiar noun interpreted it as a relational term (preposition condition: ''This is acorp my box!''), whereas those who heard the word in a labeling phrase without the final noun did not (noun condition: ''This is a corp!''). These results held even when the noun condition sentences were created by deleting the final noun of the recorded preposition condition sentences. This suggests that the set of nouns, independent of prosodic cues, allowed children to identify the new word as a relational term.

Second, children under 2 years old do not appear to use the sentence position (final vs. medial) of a novel verb systematically as a cue to its transitivity: Systematic use of this cue would predict early success in differentiating transitive sentences (''The duck is kradding the bunny!'') from intransitive sentences with two nouns (e.g., ''The duck and the bunny are kradding!''). The present work was inspired in part by toddlers' failures to differentiate these sentence types (Bavin & Growcott, 2000; Hirsh-Pasek et al., 1996; Naigles & Swensen, 2007).

Third, there is little evidence that young English speakers have robust knowledge of pronoun case. Two- and 3-year-olds make case errors in their own speech; the use of feminine accusative pronouns (*her*) as subjects is particularly common (e.g., ''Her cries a lot''; Brown, 1973; Rispoli, 1994). Consistent with this evidence from spontaneous production, Childers and Tomasello (2001) found that 2.5-year-olds more readily produced or comprehended transitive sentences containing novel verbs if they had first heard training sentences with pronoun arguments rather than sentences with only lexical

nouns, but that this pronoun-argument advantage emerged only with pronouns contrasting in animacy (e.g., ''He [verbed] it''), not with pronouns contrasting in case (''She [verbed] her''). They speculated that this limitation could be due to 2-year-olds' difficulty with the irregular English case system. In the present experiments, children needed only to know that both *she* and *her* were nouns; on the structure-mapping account, success in our task did not require using case to infer that *her* was not a subject NP.

Fourth, as noted earlier, 29- and 23-month-olds learned about a novel verb's transitivity based on hearing sentences in a dialogue (e.g., ''Jane blicked the baby!'') and later used that knowledge to interpret the verb (Yuan & Fisher, 2009, 2010). Crucial for present purposes, they did so even though the dialogue sentences contained no object pronouns. This suggests that young children can identify and interpret simple transitive sentences without the aid of case-marked pronouns (see also Gertner et al., 2006).

Taken together, these sources of evidence suggest that the number of nouns in our simple sentences played a substantial role in driving children's interpretations of a novel verb. Future experiments can further disentangle the effects of the set of NPs and potentially helpful prosodic and morphological cues in early verb interpretation, by manipulating novel verbs' prosodic properties and surrounding morphemes, independent of their transitivity.

The role of learned syntax–semantics links. The structure-mapping account posits both abstract syntactic and semantic representations, and some innate constraints on links between the two—specifically, a bias toward one-to-one mapping between nouns and participant roles. The innate syntax–semantics links permit children to infer meaning directly from simple subcategorization frames based on little or no learning. The abstract syntactic and semantic representations support these initial built-in links but also promote the quick detection and generalization of syntactic–semantic patterns that are language-specific and therefore must be learned (e.g., Gertner et al., 2006; Pinker, 1989). Strong support for early abstract representations of language input comes from evidence that infants learn a representation of their language's basic word order before speaking a single word (e.g., Christophe, Nespor, Guasti, & van Ooyen, 2003; Gervain, Nespor, Mazuka, Horie, & Mehler, 2008). Given such evidence of early abstract representations, one might propose an account of the origins of syntactic bootstrapping that relied on abstract syntactic and semantic representations, but not on innate constraints linking the two. On such an account, *all* links between syntax and semantics would be learned; given abstract syntactic and semantic representations, basic patterns of the language might be learned and generalized very quickly.

We think there are several reasons to prefer the structure-mapping account over one that equips learners with abstract representations, but with no innate links between syntax and semantics. Compelling evidence for an unlearned bias toward a one-to-one mapping between nouns and participant roles comes from the study of Home Sign (Goldin-Meadow, 2003). Deaf children without effective exposure to a conventional language invent sign systems that share properties of conventional languages. In particular, across multiple short utterances, signs with verb-like meanings occur with predictable sets of noun-like arguments (*hug* with both an agent and patient, *sleep* with only an agent). Goldin-Meadow (2003) argued that this pattern was not learned from mothers' gestures to their children, in part because the mothers rarely produced gesture combinations. This suggests that children need not learn from exposure to a conventional language that the participant roles implied by each verb's meaning can be specified by nouns in sentences; instead, children bring this expectation to the task of language creation.

Further evidence that children may not learn the relation between nouns and participant roles comes from cross-linguistic studies of verb learning. In many languages, the set of nouns in a sentence is a less reliable cue than it is in English, because many languages permit NP arguments to be omitted much more freely than English does (e.g., Mandarin Chinese; Kannada). Despite the less apparent relation between the nouns and participant roles in the input, however, learners of these languages still rely on the number of NPs as a cue to verb meaning (Lee & Naigles, 2008; Lidz et al., 2003; Yuan et al., 2010). Crucially, they do so even in preference to language-specific morphological cues that are arguably more reliable cues (Lidz et al., 2003). Such findings support the key claim of the structure-mapping account—that some fundamental relations between verb syntax and meaning might be unlearned.

Summary and Conclusions

Even 19- and 21-month-olds use subcategorization frames to interpret new transitive versus intransitive verbs, as long as the sentences are

simple enough. We suggested a mechanism by which syntactic bootstrapping could begin: On the structure-mapping account, young children have access to certain core, nonarbitrary relations between syntax and semantics. Children assume that each noun in the sentence represents a participant role in an event. As a result, they find the number of nouns in the sentence meaningful, essentially from the start of multiword sentence comprehension.

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