INTEGRATING SENTENCE-STRUCTURAL AND EVENT INFORMATION IN EARLY VERB LEARNING

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Psychology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2009

Urbana, Illinois

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ABSTRACT

Children use syntax as well as observations of events to learn verb meanings. This is known as syntactic bootstrapping. This dissertation investigated the origins and mechanisms of syntactic bootstrapping. Prior evidence suggested that two-year-olds, but not younger children, could use aspects of sentence structure to assign different interpretations to novel transitive and intransitive verbs. Persistent negative findings with younger children raised questions about the kind of knowledge young children need about syntax-semantics links in order to begin using sentence-structural information to learn verbs. In this dissertation, I reported evidence (Chapter 2) that 21- and 19-month-old children showed sensitivity to the sentence structure in interpreting novel transitive and intransitive verbs, as long as the numbe nouns in the sentence was informative. The results suggest that syntactic bootstrapping might begin with a bias in young children to assign each noun in the sentence to a core participant-role in their conceptual representations of events. Moreover, I found that 2-year-old Mandarin learners also used the number of noun phrases in novel-verb interpretation (Chapter 3), despite frequent argument omission that makes the number of noun phrases per sentence a less reliable indicator of verb argument-structure in Mandarin than in English. This extension to Mandarin learners suggests that syntactic bootstrapping is a fundamental part of verb learning, even for learners of languages (such as Mandarin) that provide much less evidence for a reliable link between noun-phrase number and verb argument-structure in the input. Finally, I demonstrated that 2-year-olds found sentence-structural information independently informative when learning about a new verb (Chapter 4). Specifically, 2-

year-olds learned about a new verb's combinatorial privileges—transitivity and participant-role number—from brief dialogues alone, and later retrieved this information to guide their interpretation of the verb when it was presented in a referential context. The results suggest that verb learning is rooted in children's learning about the combinatorial properties of verbs. Given a simple bias toward a one-to-one mapping between nouns in sentences and participant-roles in their construals of events, children can use what they learn about the combinatorial privileges of particular verbs to figure out skeletal aspects of their meanings.

To my mother and father, Mei-Mei Lee and Wan-Jung Yuan

ACKNOWLEDGEMENT

I would like to sincerely thank my advisor Cynthia Fisher for her guidance and persistent encouragement during my graduate study. Her enthusiasm has inspired me to appreciate the challenges and rewards of being a researcher of language acquisition. I would also like to thank other members of my committee—Renée Baillargeon, Gary Dell, Kara Federmeier, and Susan Garnsey—for challenging and supporting me with hard questions and valuable discussions.

I would like to extend my gratitude to all members of the Language Acquisition Lab at the University of Illinois for their assistance with conducting the experiments. I would especially like to thank Amélie Bernard, Kyle Chambers, Yael Gertner, Padmapriya Kandhadai, Kristine Onishi, Rose Scott, and Hyun-joo Song for many helpful suggestions and discussions. Special thanks to the parents and children who had participated in the project.

Finally, I would like to thank my parents, Mei-Mei Lee and Wan-Jung Yuan, my three sisters, Sherry, Sandra and Sara, my old friend Aurore Wu, and my husband Joseph Tucek, for their constant love, support and encouragement.

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CHAPTER 1

ORIGINS AND MECHANISMS OF SYNTACTIC BOOTSTRAPPING

In the first year of life, children acquire an astounding number of words. It has been estimated that between 18 months and 6 years of age, children learn about five "root" words a day (Carey, 1978). How do they accomplish such a feat? Upon hearing a new word, children no doubt turn to their experiences with the world, observing what is in their environment when the word is uttered, to begin deciphering the word's meaning. Yet observation of real-world scenes alone presents considerable ambiguity about the referent of the word (Quine, 1960). In addition to observational learning, certain conceptual biases and additional sources of information have been postulated to constrain the set of hypotheses children consider. In the case of verbs, the syntactic bootstrapping theory proposes that one additional source of information comes from the sentence structures in which verbs appear. In this dissertation, I explore the origins and mechanisms of syntactic bootstrapping.

It is clear that learning a new verb requires observing events that co-occur with the verb. To learn the full meaning of feed, for example, children must observe at least one instance of feeding to determine the particular relation conveyed by the verb. However, some aspects of verb meaning challenge views of verb learning based solely on observation of events (e.g., Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman et al., 2005; Landau & Gleitman, 1985): Verb meanings do not simply label events; instead they represent a perspective on an event. For example, pairs of verbs such as feed and eat, or give and get, denote not different world events, but different aspects of the same class

of events.

An additional source of information may fill this gap: The syntactic bootstrapping theory proposes that children use precursors of the adult's knowledge of linkages between syntax and semantics to understand sentences and therefore to learn verbs (e.g., Gleitman, 1990). Syntactic bootstrapping works because there are systematic relationships between the sentence structures verbs occur in and their semantic predicate-argument structures (e.g., Bloom, 1970; Fillmore, 1968; Fisher, Gleitman, & Gleitman, 1991; Gleitman, 1990; Goldberg, 1995; Grimshaw, 1994; Levin & Rappaport Hovav, 2005; Pinker, 1989). For example, motion verbs (e.g., walk) tend to occur in sentences with prepositional phrases, cognition verbs (e.g., think) in sentences with sentence complements, and transfer verbs (e.g., give) in sentences that have three noun phrases.

Considerable supporting evidence for syntactic bootstrapping comes from demonstrations that children as young as two years old assign different meanings to novel verbs presented in different sentence structures (Fisher, 1996; 2002a; Fisher et al., 1994; Naigles, 1990, 1996; Naigles & Kako, 1993; Papafragou, Cassidy, & Gleitman, 2007). For example, in Naigles (1990), 2-year-olds who heard a novel verb presented in transitive sentences ("The duck is gorping the bunny!") interpreted the verb as referring to a causal component of a scene, while those who heard a novel verb presented in intransitive sentences ("The duck and the bunny are gorping!") did not. Thus, by age 2, children can use simple aspects of sentences such as verb transitivity to focus on particular aspects of the same scene and assign different meanings to the novel verb. As children get older, they can use more complex sentence-structural information to interpret novel verbs. In Papafragou et al. (2007), 4-year-olds used occurrence with sentence

complements as a clue that a new verb accompanying an observed scene has mental content meaning: The children were more likely to assign mentalistic interpretations to a novel verb presented in sentences with a complement clause ("Matt gorps that his grandmother is under the covers!") than to a novel verb presented in transitive sentences ("Matt gorps a basket of food!"). Given sentences containing sentence complements, the children generated even more mentalistic interpretations if the observed event also depicted a salient mental state (e.g., a false belief held by an event participant). These examples illustrate that children use aspects of sentence-structure to guide their choice among referential options and that verb learning is constrained by this mapping between sentences and scenes.

How does syntactic bootstrapping work? I am interested in how syntactic bootstrapping might begin and how sentence-structural information is combined with event information. Specifically, what is the minimal information children need to have about links between syntax and semantics in order to begin using sentence-structural information to learn verbs? Is syntactic bootstrapping a fundamental part of verb learning in learners of different languages, or is it influenced by certain characteristics of the input language? Finally, how is sentence-structural information used in relation to referential information from observed events? The next three chapters will address each of these questions.

Can children use sentence-structural cues in the early phase of verb acquisition? Prior findings provide no evidence that children younger than two years of age can assign appropriately different interpretations to novel verbs presented in different sentence structures (e.g., see Naigles and Swensen, 2007). The lack of evidence with younger

children raises the question of how syntactic bootstrapping might begin: What kind of knowledge about syntax-semantics links should children have, and where does this knowledge come from?

For sentence-structural information to be useful in the early phase of verb learning, children would need to rely on simple knowledge about the syntax and its links to meaning. The structure-mapping view, an account of early syntactic bootstrapping, proposes that children may start by having a shallow representation of the sentence in which the verb occurs, and then map that representation onto a structured conceptual representation (Fisher et al., 1994; Fisher, 1996, 2000, 2002a; Gleitman et al., 2005). One key assumption of this account is that children have a bias to assume that each noun in the sentence specifies a semantic argument of a predicate term. Given this one-to-one mapping bias, children can represent the number of nouns that occur in sentences with the verb and use that representation to select a conceptual representation of a scene (or aspect of a scene) that has the same number of core participants. Through aligning the sentence and event representations that are structured similarly—in terms of predicates and arguments, linguistically and conceptually—children gain some insights into the verb's meaning.

In a series of experiments reported in Chapter 2, I set out to test two predictions of the structure-mapping account. First, given the simple requirements for children's representation of sentences, the use of the number of nouns as a cue to verb meaning should be observed early in verb learning, well before two years of age. Second, the structure-mapping view predicts that this sentence-to-event mapping should be constrained by children's conceptual representations of the events. In using the number of

nouns to interpret a novel verb, children's choice of event as the referent for the verb should depend on how they represent relations in the events. Findings presented in the chapter confirm these two predictions. At both 21 and 19 months of age, children are sensitive to the number of nouns in sentences when interpreting novel verbs. Moreover, their use of the number of nouns is constrained by their structured conceptual representations of events. These findings provide the first evidence that children under two years old use sentence-structural cues in interpreting novel verbs. This early use of sentence-structural cues suggests one way in which syntactic bootstrapping may start: Young children have access to certain core, non-arbitrary relationships between syntax and semantics, which serve as constraints on how they learn verbs and grammar in an early stage.

Is syntactic bootstrapping a fundamental verb-learning mechanism for learners of languages other than English? With a few exceptions, the vast majority of the research on syntactic bootstrapping has tested English learners. The number of nouns is clearly an informative cue for children learning English, in which the arguments of a verb have to be specified in the sentence under ordinary circumstances. However, in many languages such as Mandarin, noun phrases in sentences can be, and frequently are, omitted if they can be recovered in the discourse (Li & Thompson, 1981; Wang et al., 1992). The prevalence of argument omission in the world's languages raises questions about the universality of syntactic bootstrapping. Do specific properties of language such as argument omission influence learners' use of sentence-structural cues? Chapter 3 presents experimental investigations of whether Mandarin-speaking 2-year-olds use the number of nouns in interpreting novel verbs. The findings show that they do. Despite the markedly

less reliable information about the relationship between syntax and semantics in the input (Lee & Naigles, 2005), Mandarin learners, just like their English-speaking counterparts, use sentence-structural information in interpreting new transitive vs. intransitive verbs. These findings are consistent with arguments that the number of nouns is an intrinsically meaningful cue to young children. That is, children may not have to learn from the input language how to interpret the number of nouns occurring with a verb as a cue to verb meaning.

Given that sentence-structural cues such as the number of nouns in a sentence are informative to young children in verb learning, how is this sentence-structural information combined with other information sources? For example, does the usefulness of sentence-structural information depend on having referential information from a concurrently observed event? Prior experimental investigations of syntactic bootstrapping have all provided children with simultaneous access to sentence-structural and event information (Fisher, 1996; 2002a; Fisher et al., 1994; Naigles, 1990, 1996; Naigles & Kako, 1993). In Chapter 4, I report experimental findings based on a new method designed to separate the two information sources. The children first watched dialogues in which interlocutors used a novel verb in sentences of a particular structure (transitive or intransitive); next, they were presented with candidate events for the verb while they heard the verb in a syntactically uninformative context. The findings suggest that children find the sentence-structural information independently meaningful. Through experience simply listening to sentences with a novel verb, 2-year-olds can gather relevant syntactic-semantic information about the verb and later use it to guide their interpretation of the verb in a referential context.

In summary, in six experiments, I explored the origins and mechanisms of syntactic bootstrapping by testing several aspects of young children's use of sentence-structural information in verb learning. Based on the findings from these experiments, I conclude that young learners are able to use simple sentence-structural cues to interpret and learn new verbs *because they expect structural parallels between language and the relevant construal of events*. In particular, children assume a one-to-one mapping between nouns in sentences and participant-roles. As a result, they can use simple sentence-structural cues to gain insights into the semantic predicate-argument structure of a new verb. This does not require much language-specific learning about the syntax of the input language, thus allowing learners to get started with structure-guided learning in the early stages of language development and to do so even in languages that provide strikingly different degrees of evidence for a reliable link between noun-phrase number and verb argument-structure in the input. Finally, children find sentence-structural information independently meaningful, even without referential information from a concurrently observed event, attesting the basic premise of syntactic bootstrapping. Verb learning is founded by children's learning about the combinatorial properties of verbs. Given a simple bias toward a one-to-one mapping between nouns in sentences and participant-roles in their construals of events, children can use what they learn about the combinatorial privileges of particular verbs to figure out skeletal aspects of their meanings.

CHAPTER 2

COUNTING THE NOUNS AND PARTICIPANTS: LINKING SENTENCE- AND EVENT-REPRESENTATIONS IN EARLY VERB LEARNING

During the preschool years, children learn the meanings and syntactic properties of thousands of words. These two dimensions of lexical knowledge, semantic and syntactic, are intimately connected. Words come in different grammatical categories, which have different sorts of meanings (e.g., count nouns, adjectives, verbs). The role of syntactic knowledge in word learning is particularly striking for verbs. Within and across languages, verbs fall into syntactic-semantic subcategories such as transitive and intransitive verbs, among many others. Verbs are choosy about the sentence structures they accept, and verbs that occur in similar sentence structures have similar meanings (e.g., Bloom, 1970; Carlson & Tanenhaus, 1988; Dowty, 1991; Fisher, Gleitman, & Gleitman, 1991; Levin & Rappaport-Hovav, 2005; Pinker, 1989).

For example, verbs that describe one participant acting on another tend to be transitive, licensing two noun-phrase arguments ("She tickled the baby."), while those that denote internally caused one-participant actions tend to be intransitive, licensing only one argument ("The baby laughed."). Verbs that describe transfer of possession occur in sentences with three noun phrases ("She gave the baby a kiss."). Verbs of cognition and perception often accept whole sentences as their complements ("We think Lynn plays the cello beautifully"). As these examples suggest, such regular relationships between syntax and verb meaning are no accident. A central part of the meaning of each verb is a

semantic predicate-argument structure that specifies how many and what kinds of participant roles the meaning of the verb implies (Fisher, 1996, 2000; Fisher, Hall, Rakowitz, & Gleitman, 1994; Grimshaw, 1994; Lidz, Gleitman, & Gleitman, 2003; Pinker, 1989). Tickling requires both tickler and ticklee, for example, while laughing only requires a laugher. Barring interesting exceptions (to which we will return below), the syntactic behavior of each verb—the number and type of syntactic arguments the verb accepts—reflects this semantic predicate-argument structure.

The syntactic bootstrapping hypothesis holds that children exploit these regular links between verb syntax and meaning in verb learning, deriving aspects of a verb's meaning from its syntactic behavior, as well as by observing the events that accompany its use (Landau & Gleitman, 1985; Gleitman, 1990). Evidence for syntactic bootstrapping comes from many experiments showing that children between two and five years of age assign different interpretations to novel verbs presented in different sentence structures (e.g., Fernandes, Marcus, DiNubila, & Vouloumanos, 2006; Fisher et al., 1994; Fisher, 1996; 2002a; Kidd, Bavin, & Rhodes, 2001; Naigles, 1990; 1996; Naigles & Kako, 1993; Papafragou, Cassidy, & Gleitman, 2007; Scott & Fisher, 2009; Yuan & Fisher, 2009). For example, Naigles (1990) reported that 25-month-olds who heard a novel transitive verb ("The duck is gorping the bunny!") looked longer at an event in which the duck acted on the bunny than at one in which the duck and bunny both acted independently, while those who heard a novel intransitive verb ("The duck and the bunny are gorping!") did not.

Here we ask how syntactic bootstrapping begins. What do young children need to know about the relationships between verb syntax and verb meaning in order to start

using syntax to interpret new verbs? Where does that knowledge come from?

We describe two broad classes of mechanisms that might permit children to begin to use syntactic cues in verb learning.

Construction-based learning. One possibility is that children start by learning about the syntactic behavior and meanings of an initial vocabulary of verbs without the aid of syntactic cues to verb meaning. As children accumulate such structure-meaning pairs for many verbs, they gradually abstract away from the specifics of individual verbs' meanings and sentence contexts, perhaps by analogical comparison, to create an abstract construction. On this view, all of the links between verb syntax and semantics that 2- to 5-year-olds ultimately use to learn new verbs are constructed from experience with a particular language, based on considerable verb-by-verb learning. This is known as the construction-based learning view (Goldberg, 1999, 2006; Tomasello, 2000, 2003).

To illustrate, on this account children note that many English verbs, such as 'hit', 'tickle', 'hug', and 'break', share both syntactic and semantic similarities. They all occur in the structure [Noun-phrase Verb Noun-phrase], and they all describe conceptual-semantic relationships involving two distinct participant-roles. Once children have built a representation of the transitive construction that reflects these abstract similarities, they can apply it to assist in the learning of new verbs. Upon encountering a new verb in a transitive sentence structure, children can assign to it a two-participant interpretation.

A key claim of the construction account is that each language's constructions are learned as essentially arbitrary facts about the language. That is, children discover that transitive verbs describe two-participant relations, while intransitive verbs do not, in much the same way that they discover that the '-ed' affix marks the past tense in English.

Arbitrary form-meaning relations such as these must be discovered by the learner from regularities in the input language (e.g., Maratsos & Chalkley, 1980). Crucially, on this account the creation of abstract sentence schemata such as the transitive construction takes a long time. Transitive verbs vary greatly in their meanings and in the lexical items that fill their noun-phrase slots ('She tickled Bill', versus 'Eleanor broke her toy'). Generalization across these diverse items is predicted to be a protracted process, requiring children to achieve a critical mass of verbs, complete with their meaning-structure pairings, in order to detect similarities among verbs of the same subcategory.

The slow emergence of abstract constructions plays an important role in this account, because it has been invoked to explain empirical facts about language development. For example, children under about age 3 very rarely produce transitive uses of new verbs that they have only encountered in other syntactic structures (e.g., Brooks & Tomasello, 1999; Tomasello & Brooks, 1998; Olguin & Tomasello, 1993). According to the construction-based learning account, children's reluctance to extend new verbs to new syntactic structures is an indication that they do not yet possess useful abstract knowledge of constructions such as the transitive. For this reason, proponents of the construction account have typically argued that an abstract transitive construction does not emerge until nearly three years of age (Tomasello, 2000).

More recently, proponents of the construction account have acknowledged that partial abstract knowledge of the transitive construction may be in place between two and three years of age, slightly earlier than previously thought (Tomasello & Abbott-Smith, 2002; McClure, Pine, & Lieven, 2006; Goldberg, 2006). This revision accommodates findings from spontaneous and elicited language production that hint at earlier abstract

knowledge (e.g., McClure et al., 2006; see also Fisher, 2002b, and Tomasello & Abbott-Smith, 2002, for discussion of findings from Akhtar, 1999), and evidence of two-year-olds' success in certain comprehension tasks (e.g., Naigles, 1990; Fisher, 2002a). Evidence of a partially-abstracted transitive construction between ages 2 and 3 is consistent with the construction account. On this account, abstract constructions emerge gradually as the child gathers ever more examples of verbs that participate in that construction. However, in the revised view of the construction account, these signs of abstract knowledge of the transitive construction in two-year-olds suggest only a 'weak' schema of the transitive construction (Tomasello & Abbott-Smith, 2002), which might be sufficient to influence 2-year-olds' behavior in comprehension tasks with few action demands, but not in language production tasks, and which still emerge from prior learning about the structure and meaning of particular lexical combinations (Childers & Tomasello, 2001; McClure et al., 2006). Thus, on this view, children younger than about 2 years old should not be able to use syntactic-structure cues to guide verb learning.

Structure-mapping account. In contrast, we and others have proposed a structure-mapping account of early syntactic bootstrapping, on which some links between verb syntax and semantics are not arbitrary, and do not need to be learned (Fisher et al., 1994; Fisher, 1996, 2000, 2002a; Gleitman et al., 2005; Lidz, Gleitman, & Gleitman, 2003; Lidz & Gleitman, 2004).

The key assumption of the structure-mapping account is that children expect each referential term in a sentence to be a semantic argument of a predicate term. Given this one-to-one mapping bias, the set of nouns in the sentence is inherently meaningful to children, providing information about the semantic predicate-argument structure of a new

verb. The set of nouns is useful because it provides a rough distinction between transitive and intransitive verbs.

A bias toward one-to-one mapping between noun-phrases in sentences and semantic arguments of predicate terms has long been reflected in linguistic theory as a constraint on grammars (e.g., Chomsky, 1981). Compelling evidence for an unlearned bias toward one-to-one mapping comes from the phenomenon of Home Sign (Goldin-Meadow, 2003). Deaf children without effective exposure to a conventional language spontaneously develop their own sign systems that share core properties of conventional languages. Signs glossed as verbs occur with predictable sets of noun-like arguments (hug with two, sleep with one). This strongly suggests that children do not need to learn from exposure to a conventional language that each verb's logical arguments can be specified by nouns in sentences.

An example of the structure-mapping procedure is sketched in Figure 1. Suppose a toddler hears an unknown verb combined with two known nouns (e.g., "She's gorping her!"), in the context of the scene depicted in the Figure. This scene could be construed in multiple ways: One person is feeding another, who is eating; one is standing, one is sitting, and one is holding a bowl and a spoon. Even before the child knows enough about the native language to build a complete syntactic structure, she might represent the input sentence simply in terms of the verb and the set of nouns it occurs with (e.g., Fisher et al., 1994). Armed with the proposed one-to-one mapping bias, the child could infer that this two-noun sentence conveys a conceptual representation involving two participant-roles, and consequently map the sentence onto a candidate conceptual representation centrally involving both named participants (perhaps feeding). In contrast, upon hearing a sentence

containing only one familiar noun (e.g., "She's gorping"), the child could conclude that the sentence refers to a conceptual relation centrally involving the single named participant. As a result, the set of nouns in the sentence helps to determine which aspects of the world scene the child considers relevant to the meaning of the new verb.

This procedure depends on the structured nature of children's representations of both sentences and events. Representations of sentences and conceptual representations of events differ in many ways, but share structural similarities: Both kinds of representations make a fundamental distinction between relations and the entities they relate. A sentence representation includes the predicate and argument terms (e.g., the verb 'gorp' and the accompanying set of noun-phrases), while each candidate conceptual representation consists of a conceptual predicate or relation and the core participants in that relation. There is evidence that infants' conceptual representations of events possess this useful kind of predicate-argument structure (e.g., Baillargeon, 2004; Gordon, 2003). For example, 8- and 10-month-olds were more likely to notice that an object had vanished from a scene if that object had played a meaningful role in the event (e.g., a toy bear being given to someone, as opposed to a bear being incidentally carried along during a hugging event; Gordon, 2003). Such data suggest that even pre-linguistic infants represent events in terms of a conceptual predicate-argument structure, in which the important participants in an event are determined by the infant's construal of the relationship they participate in.

The structure-mapping account holds that the set of nouns in a sentence provides an unlearned guide to verb interpretation, and therefore makes a strong prediction: Sentence-structure information should play a role in very early verb learning. As soon as

children can identify some nouns in sentences and represent them as parts of a larger utterance structure, they should be able to assign appropriately different interpretations to transitive and intransitive verbs.

At what age should we expect children to succeed in such inferences? There is reason to suppose that very young children can often identify and represent the nouns in sentences they encounter. Nouns tend to dominate children's early vocabularies (e.g., Gentner & Boroditsky, 2001), and even infants are sensitive to distributional cues that could be used to identify nouns in sentences (e.g., Waxman & Booth, 2001; Booth & Waxman, 2009). Children well under two years of age can understand multi-word sentences under some circumstances, suggesting that they can represent nouns in a sentence as parts of a larger utterance structure (Hirsh-Pasek & Golinkoff, 1996; Gertner, Fisher, & Eisengart, 2006; Seidl, Hollich, & Jusczyk, 2003). For example, 18-month-olds used knowledge of English word order to interpret sentences such as "Big Bird is tickling Cookie Monster," inferring that the first noun-phrase named the agent of tickling, and the second named the patient (Hirsh-Pasek & Golinkoff, 1996). Given such findings, the structure-mapping account predicts that sensitivity to the number of nouns in novel-verb interpretation should also be observed well before two years of age.

In previous work, however, the youngest children found to be able to use sentence-structural cues to interpret novel transitive and intransitive verbs were two years old. As noted above, 25-month-olds assigned appropriately different interpretations to novel verbs presented in transitive (1) versus intransitive sentences (2) (Naigles, 1990). This finding has been replicated many times, but children younger than two years old have generally failed in this task (Hirsh-Pasek, Golinkoff, & Naigles, 1996; Bavin &

Growcott, 2000; see Naigles & Swensen, 2007, for a review). The younger children's failure to use a new verb's transitivity in selecting an interpretation could be interpreted as consistent with the predictions of the construction account. These early failures are just what we should expect if children must learn the semantic significance of verb transitivity, based on a substantial set of previously-learned verbs, before they can use this fundamental aspect of syntactic structures to guide verb learning (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.

An alternative interpretation, however, is that these early failures result from the linguistic complexity of the stimuli. In the previous experiments, the number of nouns in the stimulus sentences was made uninformative. Both transitive and intransitive sentences contained two nouns, as shown in (1) and (2). This tactic was adopted for good reasons: By including the same referential terms in both the transitive and intransitive test sentences, the investigators ensured that 2-year-olds' success in the task reflected their sensitivity to the syntactic structure of the sentence itself, rather than their reliance on what characters were mentioned by name (versus not mentioned) in the sentence. However, to assign different interpretations to (1) and (2), children must already have learned the English syntactic and morphological features that differentiate transitive sentences from intransitive sentences containing two nouns. These include the conjunction 'and' that links the two noun-phrases in (2) into a single complex noun-phrase, the plural-marked auxiliary verb 'are', and the fact that 'Noun-Noun-Verb' is not the canonical order for English transitive sentences. The structure-mapping account

predicts early errors in the interpretation of such sentences (Connor, Gertner, Fisher, & Roth, 2008; Gertner & Fisher, 2009): If very young children assume that each noun should be assigned a participant-role, and have not yet acquired much knowledge about English syntax and morphology, they should be unable to tell two-noun intransitive sentences from true transitive sentences.

The present experiments asked whether children under two years old would succeed in assigning appropriately different interpretations to new transitive and intransitive verbs if the number of nouns in the sentence is made informative. To address this question, we adapted a tactic used by Fisher (1996, 2002a). Fisher labeled unfamiliar agent-patient events with new transitive ("She's pilking her over there") or intransitive verbs ("She's pilking over there"). The use of ambiguous pronouns yielded sentences that differed only in their number of noun-phrases, thus isolating the effect of sentence structure on verb learning. Verb interpretation in Fisher's experiments was assessed by asking children to point to the participant whose role each verb described ("Which one is pilking (her) over there?"). 2.5-year-olds and older children more often chose the agent of action as the subject of a transitive than an intransitive verb. In the present study, to simplify the task for younger children, we used a looking-preference comprehension task. This task relies on the natural tendency of children and adults to look at scenes related to the sentences they hear (e.g., Cooper, 1974; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Tanenhaus, Spivey, Eberhard, & Sedivy, 1995).

Experiment 1

Experiment 1 asked whether 21-month-olds assign appropriately different interpretations to novel transitive and intransitive verbs when the number of nouns in sentences is informative. In the critical test item, 21-month-olds watched side-by-side videos showing two novel events (Figure 2). One was a one-participant event depicting a solo action (a man making arm-motions as in jumping-jacks), and the other was a two-participant caused-motion event (one man causing another to bend forward and back). Children were assigned to one of three sentence conditions. In the transitive and intransitive conditions, children saw this event-pair accompanied by audio containing a novel verb in transitive (e.g., 'He's gorping him!') or intransitive sentences (e.g., 'He's gorping!'), respectively. The transitive and intransitive conditions thus differed in the number of nouns in the sentences. A third, neutral condition, was included to assess children's baseline preferences for the two events. Children in this condition heard neutral audio with no novel verb (e.g., 'That looks fun! What do you see?').

The structure-mapping account predicts that 21-month-olds should assign appropriately different interpretations to novel transitive and intransitive verbs, because these two stimulus sentences differ in their number of nouns. Children in the transitive condition, upon hearing "He's gorping him," should note that this sentence contains two nouns, and infer that the new verb refers to an activity involving two participants. We therefore predicted that children in the transitive condition would look longer at the two-participant test event (and less at the one-participant event) than would children in the intransitive or neutral conditions. Children in the intransitive condition, upon hearing

"He's gorping," should note that this sentence contains only one noun, and infer that the new verb refers to an activity involving one participant.

Notice that the one-noun intransitive sentence "He's gorping" is less constraining than the two-noun transitive sentence given the referential contexts provided: The intransitive sentence could refer either to the solo action in the one-participant event or to a component of the two-participant event, perhaps the motion of the seated boy. Because both test events provide plausible referents for an intransitive verb, we predicted that children in the intransitive condition would not display a preference for either test event relative to children in the neutral condition. This prediction that the intransitive verb will not strongly constrain children's choices in this task is consistent with prior findings: For example, Fernandes et al. (2006) and Fisher (2002a) reported that 2-year-olds readily interpreted a novel intransitive verb as referring to the (externally-caused) motion of a patient in a causal event.

Method

Participants

Twenty-four 21-month-olds (Mean = 21.3 months; range 19.8 to 23.5; 12 girls and 12 boys), all native English-learners, participated in the experiment. Eight children were randomly assigned to each of the three experimental conditions (Transitive, Intransitive and Neutral). 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. Each child received a book as thanks for his or her participation. One additional child was tested but not included due to inattentiveness.

Children's productive vocabularies, measured using the short form of the MacArthur-Bates CDI Level II (Fenson et al., 2000), ranged from 0 to 82, with a median of 30.

Apparatus

Children sat on a parent's lap in a dimly-lit room, facing two 20" color TV screens at a distance of about 30". The two TV screens were approximately at child's eye level, laterally separated by 12". The audio stimuli were presented from a centrally-positioned concealed loudspeaker. A hidden camera, centered between the TV screens, recorded the child's eye-movements. Parents wore opaque glasses so that they could not see the video stimuli during the experiment. Equipment other than the TV screens was concealed behind a wooden barrier painted black, with openings for the camera and loudspeaker covered with black mesh; white side curtains blocked the child's view of the rest of the room.

Materials

The children watched a synchronized pair of videos showing people performing simple actions. The accompanying soundtrack was recorded by a female native English speaker.

Procedure

The procedure consisted of three items: two practice items involving familiar verbs (one intransitive verb, clap, and one transitive verb, tickle), and one critical test item involving a novel verb (gorp). Each item consisted of two 8s trials in which a synchronized pair of video events was presented, accompanied by a single soundtrack.

The procedure began with the first practice item, involving the familiar intransitive verb clap. First, a single sentence containing the practice verb was presented

during a 4s blank-screen interval ("He's gonna clap!"). Next, two 8s video events played simultaneously, one on each screen, while children heard the stimulus sentence "He's clapping!" three times. The target video showed a man clapping; the distracter video showed a different man pretending to sleep. Next, during a 3s blank-screen interval, children were prompted to "Find clapping!". Finally, the 8s video events were presented again, while children heard "He's clapping. Find clapping! Find clapping!". Thus, the familiar verb 'clap' was presented 5 times in intransitive sentences, and 3 times as a gerund in prompts to "Find clapping".

This procedure was repeated with the familiar transitive verb tickle. Thus, children heard the verb tickle 5 times in transitive sentences (e.g., "She's gonna tickle her!" and "She's tickling her!") and 3 times in prompt sentences ("Find tickling!"). The target event showed one woman tickling another; the distracter event showed two different women, one feeding the other.

The practice items were designed to familiarize the children with the task, by teaching them that one of the two video events matched the soundtrack on each trial. To help children notice the correspondence between one video event and the soundtrack, we designed the first practice item such that the matching event (clapping) was much more interesting than the distracter event (sleeping); in the latter event the actor moved very little. This made it very likely children would look at the matching event during the first practice item, highlighting the relationship between the audio and the video stimuli. Within each practice item, target and distracter events were paired so that the number of participants was the same on both screens. Thus, during the practice trials, the children had to rely on their knowledge of the verb's meaning, and not the number of nouns in the

sentence, to identify the matching screen. The matching side (left or right) differed between the two practice items.

Finally, in the critical test item, the novel verb 'gorp' was presented in the same manner described for the practice items. The two novel events are shown in Figure 2. Children heard the novel verb in either 5 transitive sentences (Transitive condition: "He's gorping him!"), or in 5 intransitive sentences (Intransitive condition: "He's gorping!"), or heard 5 sentences that did not contain the novel verb and were neutral with respect to which video they described (Neutral condition: "That looks fun!" "What do you see?").

In both the practice and test items, the gender of the actors in the paired events was the same, so that the children could not use pronoun gender to find the matching event. Each actor appeared in only one event. Side of presentation of the events was counterbalanced with sentence condition.

Coding

We coded where the children looked (left, right, or away) during the 8s trials, frame by frame from silent video. Reliability was assessed for 6 randomly selected children; coders agreed on 98% of video frames.

Preliminary analyses of times spent looking away from the two test events (averaged across the two 8s trials) revealed no reliable effect of sentence condition ($F < 1$), suggesting that the children in the three sentence conditions tended to look away about equally, and equally briefly (transitive: $M = .31$, $se = .20$; intransitive: $M = .51$, $se = .21$; neutral: $M = .55$, $se = .17$). Given the uniformity of time spent looking away, we conducted our analyses on a single measure: the proportion of time spent looking at the two-participant event, out of total time spent looking at either the two- or the one-

participant event. The average of this proportion across the two 8s test trials was our dependent measure.

Preliminary analyses of test-item performance revealed no interactions involving sentence condition and sex, whether children's looking-time to the matching screens in the practice trials was above or below the median, or whether children's vocabulary level was above or below the median. Thus, the data were collapsed across these factors in subsequent analyses.

Results

Table 1 shows the 21-month-olds' mean proportion of time spent looking at the two-participant event, out of total looking-time to either test event. As the Table shows, 21-month-olds' looking preferences were influenced by the sentence context: Those 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 who heard no novel verb. These observations were confirmed by an ANOVA that revealed a significant effect of sentence condition ($F(2,21) = 4.32$, $p = .027$) on the average proportion of looking-time to the two-participant event.

Planned comparisons were conducted to test the main predictions of the structure-mapping account. This account predicts that children in the Transitive condition should show a greater preference for the two-participant event than would children in the intransitive or neutral baseline conditions. These predictions were confirmed: Children in the transitive condition looked reliably longer at the two-participant event than did either those in the intransitive ($t(14) = 2.45$, $p = .028$) or neutral conditions ($t(14) = 2.47$, $p = .027$). The looking preferences of children in the intransitive and neutral conditions did

not differ ($t(14) < 1$, $p = .44$). Non-parametric Mann-Whitney tests confirmed these results (transitive versus intransitive: $U = 11$, $p = .028$; transitive versus neutral: $U = 11$, $p = .028$; intransitive versus neutral: $U = 26$, $p > .5$).

Additional results

To confirm the key difference between the transitive and intransitive conditions, an additional group of 16 21-month-old children (Mean = 21.3 months; range 19.9 to 22.4; 8 girls and 8 boys) was tested in the transitive and intransitive conditions in another laboratory. Children were recruited in Cambridge, MA, using the same methods described above. The procedure and materials were identical to those described above with several exceptions: the synchronized videotaped events were projected onto a single large screen, with the hidden camera beneath it; a different novel verb was used (stipe); a different pair of novel events was used for the novel-verb test item (Figure 3); the novel-verb sentences contained feminine rather than masculine pronouns, appropriate for the new novel events. The one-participant event showed a woman bouncing on a yoga ball, and the two-participant event depicted a woman wheeling another woman back and forth in a red wagon. Half of the children were assigned to the transitive condition ("She's stiping her!"), and half to the intransitive condition ("She's stiping!").

There was again no effect of sentence condition on how long the children spent looking away in the test item ($t < 1$): The children in the two sentence conditions tended to look away about equally, and briefly (transitive: $M = .21$, $se = .09$; intransitive: $M = .31$, $se = .23$). Preliminary analyses of test-item performance revealed no interactions involving sentence condition and sex, whether children's looking-times to the matching screen in the practice trials were above or below the median, or children's vocabulary

group (vocabulary score above or below the median). Thus, the data were collapsed across these factors.

As Table 1 indicates, these additional data revealed the same pattern of results found in the main experiment: Children in the transitive condition looked significantly longer at the two-participant event than did those in the intransitive condition (transitive: $\underline{M} = .70$, $\underline{se} = .06$; intransitive: $\underline{M} = .49$, $\underline{se} = .04$; $\underline{t}(14) = 2.86$, $\underline{p} = .013$). This result was confirmed by a Mann-Whitney test ($\underline{U} = 9$, $\underline{p} = .015$).

Discussion

The results of Experiment 1 are consistent with a key prediction of the structure-mapping view. When the number of nouns in the sentence was made informative, the transitivity of the novel verb strongly influenced 21-month-olds' attention to the two test events. Those who heard the novel verb in transitive sentences looked longer at the two-participant event than did those who heard the novel verb in intransitive sentences or those who heard neutral sentences with no novel verb. This suggests that children interpreted a transitive sentence containing two nouns as requiring a referent event with two participant-roles. The children who heard the novel verb in intransitive sentences containing only a single noun, in contrast, did not show a clear preference for one event over the other, relative to those who heard neutral sentences with no novel verb. This lack of preference suggests, reasonably enough, that the children readily interpreted the intransitive verb as referring either to a component of the two-participant event or to the one-participant event. The striking difference between the transitive and intransitive conditions in the present results, however, makes clear that these 21-month-olds

interpreted novel transitive and intransitive verbs differently, when the number of nouns was informative.

This is the first direct evidence that children younger than age 2 use sentence-structure cues to assign different interpretations to novel transitive and intransitive verbs. We proposed that the prior negative findings with children younger than 2 were due, not to toddlers' ignorance of the semantic significance of transitivity, but to the relatively complex test sentences, which required considerable language-specific knowledge to generate a correct description of the sentence's phrase structure. Positive findings were obtained in the current experiment, in which we simplified the linguistic materials such that the number of nouns in each stimulus sentence was informative. Together, these findings support a key prediction of the structure-mapping account: Even children under two years old, who have much to learn about the syntax and morphology of the native language, can use sentence-structural cues in verb learning if the number of nouns is informative.

Experiment 2

The results of Experiment 1 support the hypothesis that simple sentence representations—the number of nouns in sentences—are employed by young children in their interpretation of novel verbs. 21-month-olds who heard a novel verb in two-noun transitive sentences mapped the verb to a two-participant event, whereas those who heard the novel verb in one-noun intransitive sentences did not. The finding provides support for a key prediction of the structure-mapping account. By hypothesis, when provided with a sentence and candidate referential scenes, children create structured

representations of both. Through aligning structurally similar representations of the sentence and of the events, children uncover aspects of verb meaning. In this case, as illustrated by Figure 1, we propose that children who heard a novel transitive verb mapped their two-noun sentence representation onto a two-participant event representation, and thus inferred that the verb 'gorp' referred to the 2-participant event.

As mentioned before, the informativeness of sentence representations on this account depends on the structured nature of children's conceptual representations of events. For structure-mapping to work, children need conceptual representations that are fundamentally of the same kind as the predicate-argument structures underlying the meanings of verbs -- structured in terms of relations and the entities they relate, or conceptual predicates and arguments. As a result, a participant in a child's construal of the event should be someone who plays an essential role in a coherent conceptual relation, not simply someone who is present in the scene. The nature of children's structured conceptual representations thus must constrain their use of the number of noun-phrases in verb interpretation. For example, given a two-noun sentence containing a novel transitive verb ("He's gorping him!"), children should map their representation of this sentence, not to just any event in which two people are present (e.g., one person acts independently while another stands nearby waiting for a bus), but to an event in which two entities are jointly involved in a conceptually coherent relation, and thus are core participants (e.g., one person acts on another).

Pre-linguistic infants naturally construe events in terms of relationships among entities (e.g., Baillargeon, 2004; Gordon, 2003). In determining whether an entity counts as a core participant in a given event, infants take into account the entity's relevance to

the conceptual coherence of the event. For example, 8-month-olds treated a toy as central to a 'giving' event (actor A gave actor B the toy), but not to a 'hugging' event (actor A hugged actor B while holding the toy; Gordon, 2003). At least for inanimate objects, an entity is considered a core participant in an event depending on the relevance of its role to the overall event, not based on its mere presence. In determining whether an object is an integral part of an event, infants may also consider an agent's intentions. For example, 9-month-olds treated an object as an integral part of the event if the agent in the event displayed a clear intention on the object (e.g., reaching for and grasping the object), but not if the agent's intention toward the object was unclear (e.g., flopping the back of her hand onto the object; Woodward, 1999). Moreover, given an entity that plays an essential role in a caused-motion event, infants as young as 6 months old encode specific information about the object's role in the event, such as whether it is the instigator of caused motion or the entity whose motion is externally caused (Leslie & Keeble, 1987; Oakes & Cohen, 1990; Rochat et al., 2004; Schlottmann & Surian, 1999). All of these findings suggest that pre-linguistic infants encode detailed information about the relational dynamics of an event that allow them to distinguish between core, or argument-like, participants and merely-present entities.

These structured conceptual representations help to guide the mapping between sentences and events in early sentence interpretation. When presented with a transitive sentence containing a familiar verb, such as "She's kissing the keys," 14-month-olds interpreted the sentence as referring to an event in which the named entities were involved in the relation described by the verb (a woman kissing keys while holding a ball), and not to an event in which there was both kissing and keys (a woman kissing a

ball while holding keys) (Hirsh-Pasek & Golinkoff, 1996). This result makes clear that infants mapped their representation of the sentence onto a structured representation of the event. In this case, however, the infants were guided by their knowledge of the verb kiss to select the appropriate event. If the verb had been 'hold' instead of 'kiss', infants would have made different choices between the referential options. Without knowledge of a verb's meaning, how might young children be guided by structured conceptual representations in interpreting a new verb?

A recent finding suggests that even when infants encounter an unknown verb, their interpretation is guided by expectations of structural parallels between events and language. Brandone et al. (2006) habituated 18-month-old infants to a video depicting a single-participant event with a second entity present in the scene (a girl moving her arm near a set of balloons fastened to the wall). During habituation, the scene was accompanied by a novel verb in a syntactically neutral form ("Tooping!"). After habituation, the infants saw the same visual display, but this time accompanied by either a transitive sentence ("She's tooping them") or an intransitive sentence ("She's tooping"). Infants looked longer at the same scene when it was accompanied by the transitive sentence than when it was accompanied by the intransitive sentence, suggesting that they had difficulty finding an interpretation for a novel transitive verb, but not a novel intransitive verb, in this scene. This suggests that the toddlers expected the number of core participants in an event—not merely the number of visible entities—to map onto the number of verb arguments. The toddlers evidently did not consider the set of balloons in the scene to be a core participant of the main event and, consequently, did not expect it to be an argument of the verb.

Taken together, the findings discussed here provide evidence that young children's conceptual representations are usefully structured in terms of relationships and the entities they relate. Moreover, these structured representations help constrain the mapping between sentences containing familiar verbs (e.g., "She's kissing the keys!") to events. Brandone et al.'s (2006) findings further suggest that these structured conceptual representations constrain toddlers' interpretation of novel verbs as well. However, because Brandone et al.'s study was designed to test the hypothesis that young children's representations of events would guide their predictions about the transitivity of an unknown verb, their study did not directly compare the interpretation of transitive and intransitive novel verbs in the presence of a two- and one-participant event. Thus, the study does not tell us whether young children are guided by the same structured conceptual representations when they use the number of nouns in the sentence to choose a sensible interpretation for a new verb.

Experiment 2 built on these findings, by asking whether 21-month-olds' interpretation of novel transitive and intransitive verbs is constrained by their structured conceptual representations of events. The design was similar to that of Experiment 1, except that during the critical test item, children were presented with a two-participant event and a one-participant event situated in a scene containing two people (see Figure 4). Thus both test events depicted two actors, but the two events differed in whether the two actors were jointly engaged in a coherent action. In one event (the two-participant event), two actors engaged in a caused-motion action: One woman rotated another woman on a tall swivel chair by pulling on the ends of a sash wrapped around her waist. In the other event (the bystander event), the two actors had no obvious relationship with

each other: One woman performed a solo action, bouncing on a yoga ball, while the other stood idly nearby, looking around and moving slightly, as if waiting for a bus. Children were assigned to one of three conditions. In the transitive and intransitive conditions, children heard a novel verb in transitive (e.g., "She's flomming her!") or intransitive sentences (e.g., "She's flomming!"), respectively. In the neutral condition, children heard neutral audio with no novel verb (e.g., "What do you see?' 'That looks fun!").

The structure-mapping account predicts that children will be guided by their structured conceptual representations of events in their use of the number of nouns to interpret a novel verb. Children in the transitive condition, upon hearing "She's flomming her!", should interpret the verb as referring to an event in which two core participants are involved in argument-like roles in a noteworthy relation, and not to any scene that contains two people. We therefore predicted that children in the transitive condition would look longer at the two-participant event (and less at the bystander event) than would children in the intransitive or neutral conditions. Children in the intransitive condition, upon hearing "She's flomming," should interpret the verb as referring to an activity involving one participant. As in Experiment 1, because both test events provide plausible referents for the intransitive verb, we predicted that children in the intransitive condition would not display a preference for the two-participant or bystander event relative to children in the neutral condition.

Even though we designed the bystander video to suggest no noteworthy relation between the two visible people, placing them in the same scene inevitably introduced a relationship between them. For example, the bystander might be described as ignoring the actor; at the very least, she is standing next to her. Experiment 2 was intended as a first

attempt to explore children's biases in determining what counts as a participant and what counts as a relation when mapping a sentence containing a novel verb to an event. In the two-participant event, each actor plays a role that is relevant to the same coherent event, with one exhibiting a clearly goal-directed behavior toward the other. In the bystander event, in contrast, there is no obvious coherent structure that ties together the actions of the two actors. In essence, while the task used by Hirsh-Pasek and Golinkoff (1996) asked whether toddlers knew that a transitive sentence containing a familiar verb ("She's kissing the keys") picked out a particular relation (as opposed to any relation) between the named entities, our task explored whether toddlers know that a transitive sentence containing an unknown verb picks out some structured relation (as opposed to no apparent relation) relating the named entities.

Method

Participants

Twenty-four 21-month-olds (Mean = 20.6 months; range 20.0 to 21.6; 12 girls and 12 boys) participated in the experiment. Children were randomly assigned to each of three experimental conditions (Transitive, Intransitive and Neutral). All were native speakers of English, from the same population as in the previous experiment. Five additional children were tested and eliminated due to inattentiveness (4) or side-bias (1). The distribution of productive vocabulary scores was similar to that of Experiment 1, with a median of 25.5 and a range from 8 to 85.

Apparatus

The apparatus was identical to that of Experiment 1.

Materials and Procedure

As in Experiment 1, children received three items. The first two were practice items involving familiar verbs, one intransitive (jump) and one transitive (hug), and the third was the critical test item involving the novel verb (flom). As in Experiment 1, within each item, a pair of video events was simultaneously presented in two 8s trials. The key manipulation in the test item was similar to that of Experiment 1, with the exception that a bystander was added to the one-participant test event (see Figure 4). In this new bystander event, one actor was engaged in a solo action while another stood nearby as an unrelated bystander, looking around (but never at the other actor) and moving slightly. To reduce the novelty of the bystander in test event, we also added a bystander to each of the practice events that involved only one participant. Thus, all events in all items depicted two actors.

Due to the complexity introduced by the addition of a bystander in some events, a preview period was inserted at the beginning of each item as a new feature in this experiment. During this preview period, each of the video events for the item was presented alone for 5 seconds. This gave children a chance to study each event by itself, before the events were simultaneously presented during the two 8s trials. The structure and timing of each item will be described below.

The first practice item involved sentences containing the familiar verb jump. The target event displayed one man repeatedly jumping up and down while another man sat nearby as a bystander; the distracter event depicted one man pretending to sleep while another man sat nearby as a bystander. This first item began with a preview period: After a 3s blank-screen interval accompanied by a prompt sentence ("Hey watch!"), one event

was displayed alone for 5s, accompanied by uninformative audio ("Look here. Watch this!"). After a 2s blank-screen interval during which children heard another prompt ("Oh look!"), the other event was previewed on the other TV screen in the same manner. These 5s previews of the events were followed by a 6s blank-screen interval, in which the children heard "Now watch! He's gonna jump. He's gonna jump." Then the two 8s video events were presented simultaneously, while children heard the stimulus sentence "He's jumping!" three times. Next, during a 6s blank-screen interval, children heard the familiar verb in a stimulus sentence one more time, this time in past tense ("He jumped!"), and were prompted to "Find jumping!". Finally, the 8s video events were presented again, while children heard "He's jumping. Find jumping! Find jumping!". Thus, the trial structure was similar to that of Experiment 1 except for two modifications. First, the blank-screen intervals before and between the two 8s trials were lengthened to 6 seconds from 4 (for before trials) and 3 (for between trials) seconds. Second, we provided two more sentences for these blank-screen intervals so that the children heard a total of 7 sentences containing the verb before and during the two trials. These modifications resulted in greater spacing of the two trials as well as more supporting sentence context for each item, designed to accommodate the potentially confusing presence of bystanders in the video stimuli.

This procedure was repeated with the second practice item involving the familiar verb hug and another pair of familiar video events. The target event showed one woman hugging another woman; the distracter event showed one woman feeding another woman. As in Experiment 1, these practice items were designed to familiarize children with the task, teaching them that one video would match the soundtrack on each trial.

Finally, the test item presented the pair of novel events shown in Figure 4. Both events contained two actors. As described above, the two actors in the two-participant event were engaged in a caused-motion action, while no particular relationship linked the two actors in the bystander event. The soundtrack that accompanied the events varied for the three sentence conditions. In the transitive condition, the novel verb was presented in 7 transitive sentences ("She's stiping her!"); in the intransitive condition, the novel verb was presented in 7 intransitive sentences ("She's stiping!"), while in the neutral condition, neutral audio containing no novel verb was presented (e.g., "What do you see?" "That looks fun!").

In each of the items, as in Experiment 1, the gender of the participants in the paired events was the same, so that the children could not use pronoun gender in the sentences to identify the matching event. Each participant appeared in only one event. Side of presentation of the events was counterbalanced with the order of previews and sentence condition.

Coding

Coding was carried out as in Experiment 1. Reliability was assessed for 6 randomly selected children; coders agreed on 98% of video frames.

A preliminary analysis revealed no effect of sentence condition on look-away times ($F < 1$). Children in the three sentence conditions looked away from the test events about equally, and fairly briefly (transitive: $M = .58$, $se = .17$; intransitive: $M = .41$, $se = .08$; neutral: $M = .36$, $se = .09$). Analyses were therefore conducted on the same dependent measure as in Experiment 1, the average proportion of looking-time to the two-participant event, out of the total time spent looking at either test event. As in

Experiment 1, preliminary analyses of test-item performance revealed no interactions involving sentence condition and sex, whether children's match-proportions in the practice trials were above or below the median, or whether their vocabulary were above or below the median. Thus, the data were collapsed across these factors in subsequent analyses.

Results

As Table 1 shows, 21-month-olds' preference for the two-participant event varied with sentence context: Those 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 who heard no novel verb. An ANOVA on the average proportion of looking-time to the two-participant event revealed a main effect of sentence condition ($F(2,21) = 4.69$, $p = .021$). Planned comparisons revealed that children in the transitive condition looked reliably longer at the two-participant event than did those in the intransitive ($t(14) = 2.51$, $p = .025$) or neutral condition ($t(14) = 2.67$, $p = .018$). There was no reliable difference between the intransitive and neutral groups ($t(14) < 1$). Non-parametric Mann-Whitney tests provided converging results (transitive versus intransitive: $U = 11$, $p = .028$; transitive versus neutral: $U = 14$, $p = .065$; intransitive versus neutral: $U = 29$, $p > .7$). Thus, despite the addition of a bystander to the one-participant event, Experiment 2 duplicated the results of Experiment 1.

Discussion

Experiment 2 replicated and extended the findings of Experiment 1: Young children not only assign different interpretations to novel transitive and intransitive verbs when the number of nouns in the sentences is informative, but their use of the number of

nouns in verb interpretation is guided by their structured conceptual representations of events. 21-month-olds who heard the novel verb in transitive sentences looked longer at the two-participant event than did those who heard the novel verb in intransitive sentences, or than did those who heard neutral sentences containing no novel verb. In contrast, those who heard a novel intransitive verb in sentences with one noun did not show a clear preference for either test event, relative to those who heard neutral sentences. This suggests that the children interpreted the novel transitive verb, but not the novel intransitive verb, as referring to a relational event involving two core participants. It takes more than the presence of two people for an event to be considered a likely referent for a novel transitive verb. These results suggest that the children mapped their representation of the test sentences onto a conceptual representation that was structured in terms of coherent relationships among entities, and consequently assigned a relational meaning to a novel transitive verb.

As in Experiment 1, the 21-month-olds who heard a novel intransitive verb did not have a preference for the bystander event beyond that of those who heard neutral sentences. This lack of a strongly preferred interpretation for the intransitive verb is again reasonable given that the one-noun intransitive sentence "She's flomming" could plausibly describe aspects of the bystander event (the solo action or even the fidgeting of the bystander) or components of the two-participant event. As in Experiment 1, the intransitive structure provides less constraint on interpretation than does the transitive structure, given the referential choices available.

The results of Experiment 2 add to the prior evidence of conceptual constraints on mapping between language and events (Hirsh-Pasek & Golinkoff, 1996; Brandone et al.,

2006). Even without knowledge of a verb's meaning, young children are guided by structured conceptual representations to assign a relational interpretation to an unknown verb in transitive structure. The results are also consistent with evidence from older children: Naigles (1990) found that 25-month-olds interpreted a novel transitive verb ("The duck is gorping the bunny!") as referring to a relational two-participant event (the duck bending the bunny), and not to an event in which the both named characters were present but did not interact with each another in a noteworthy relation (the duck and the bunny each waved his own arm).

Experiment 3

In Experiment 3, we extended our investigation of structure-guided learning to younger infants, 19-month-olds. The structure-mapping account predicts that children should be able to interpret novel transitive and intransitive verbs differently as soon as they are able to identify some nouns and represent them as part of a multi-word sentence. Infants as young as 14 to 16 months old sometimes succeed in understanding transitive and intransitive sentences containing familiar verbs (Hirsh-Pasek & Golinkoff, 1996; Seidl et al., 2003; Lidz & Baier, 2008). For example, after watching a book hit an apple, 15-month-olds appropriately interpreted the question "What hit the apple?" by looking at the agent (book), rather than at the patient (apple), of the hitting event (Seidl et al., 2003). Given these findings of infants' multi-word comprehension, we predict that children even younger than the 21-month-olds tested in Experiments 1 and 2 should be able to use the number of nouns to assign different interpretations to novel transitive and intransitive verbs, perhaps with more support for the successful parsing of the test sentences. As a

first step, we tested this prediction with 19-month-olds, using materials from Experiment 1.

Experiment 3 was similar to Experiment 1, with several modifications of the materials and procedure designed to make the task easier for younger infants. First, at the beginning of the session, infants watched a monologue video in which a woman spoke on the telephone and used a novel verb in multiple sentences, either all transitive ("Hey! Michael's gonna gorp Grandpa!") or all intransitive ("Michael's gonna gorp!"). Second, prior to the critical test item, the infants received previews of the test events, presented one at a time accompanied by neutral audio (e.g., "Look at this!"). These modifications gave the infants an opportunity to hear the novel verb, to observe the new verb's syntactic properties, and to inspect the novel events before they encountered the novel verb and video clips presented together in the test item. In addition, the blank-screen intervals between test trials within each item were lengthened slightly and contained additional instances of the test sentences (e.g., "He gorped him!"), again to give the infants more exposure to the verb in its syntactic context.

In addition to extending the investigation to younger infants, Experiment 3 had a second goal. Recent findings have raised questions about the robustness of young children's use of sentence structure in verb learning. Dittmar, Abbot-Smith, Lieven and Tomasello (2008) explored the ability of German-learning 21-month-olds to use word order and case marking to understand transitive sentences containing novel verbs (e.g., "The frog is tamming the monkey" vs "The monkey is tamming the frog"). The children succeeded in this task, but only following familiar-verb practice trials that were highly similar to the novel-verb test trials (e.g., "The frog is washing the monkey"). Dittmar et

al. (2008) argued that learning or priming within the experiment was necessary for such young children to use syntactic knowledge to interpret sentences containing new verbs. One way this could happen, as Dittmar and colleagues suggested, is that useful syntactic/semantic representations (e.g., linking the word 'frog' in sentence-initial position with the presence of a frog playing an agent's role') could have been primed during the familiar-verb practice trials, thus supporting successful performance in the test trials. A similar argument could be directed at our own findings in the present paper. For example, in Experiment 1, in the first practice trial, children heard a familiar verb in one-noun sentences ("He's clapping") and saw a solo action on both videos; in the second practice trial, they heard a familiar verb in two-noun sentences ("She's tickling her") and saw a two-participant event on both videos. A slightly more abstract version of Dittmar et al.'s. argument (2008) could apply here: By activating useful syntactic/semantic representations (such as 'two-noun sentence' and 'two-participant event'), these familiar-verb practice trials could have supported children's later test performance by either teaching them or priming them to link the number of nouns in the sentence with the number of participant-roles in events.

To eliminate this possibility, we modified the practice trials in Experiment 3 so that they were much less similar to the novel-verb test trials than were those in Experiments 1 and 2. Both practice items in Experiment 3 used the same familiar verb (has) and asked the infants to identify the matching event based on what object the single actor in each event held in her hands ("She has a shoe!" and "She has a hat!"). These practice items did not set up a contrast between a verb occurring in one-noun sentences and a verb occurring in two-noun sentences with one-participant and two-participant

matching events, as did those in Experiments 1 and 2. This change made the practice items much less similar to the test trials, reducing the opportunity for infants to learn to map the number of nouns that occur with a verb to the same number of participants in an event. As in Experiments 1 and 2, however, these revised practice items still served the purpose of indicating to the infants that one video matched the soundtrack in each item.

Method

Participants

Thirty-six 19-month-olds (Mean = 18.9 months; range 18.1 to 19.9; 18 girls and 18 boys) were tested. Twelve were randomly assigned to each of the three experimental conditions (Transitive, Intransitive and Neutral). All were native speakers of English. Eleven additional infants were tested and eliminated due to fussiness (2), side bias (2), inattentiveness (4), because they spent less than 25% of the time in the practice items looking at the matching screen (1), or because their proportion of looking-time to the two-participant test event was more than 3 SD from the mean of their condition (2). The median productive vocabulary was 17, with a range from 3 to 57. Approximately half of the infants (19 total; Transitive: 5; Intransitive: 6; Neutral: 8) had "not yet" started combining words in production, according to parental report (the response options are "not yet", "sometimes", and "often"). About a quarter of the infants (Transitive: 1, Intransitive: 4, Neutral: 3) had started combining words "sometimes", and a quarter of the infants (Transitive: 6, Intransitive: 2, Neutral: 1) had started doing so "often".

Materials and Procedure

The stimuli were color videos of one woman talking on the telephone and of people performing actions accompanied by soundtracks recorded by a female native

English-speaker. As in the previous experiments, the videos were combined into synchronized pairs for presentation on the two screens.

The procedure consisted of a monologue phase, a practice item involving the familiar verb (has), and a critical test item involving the novel verb (gorp) (see Figure 5).

The procedure began with the monologue phase, designed to provide these younger infants with additional exposure to the novel verb and its syntactic properties. This monologue phase showed a woman using the novel verb gorp in sentences as she talked on the telephone. The monologue consisted of two 4-sentence video clips separated by a 2s interval. The same monologue video-clip appeared on both screens simultaneously. In the transitive condition, the verb was presented in a total of 8 transitive sentences; in the intransitive condition, the verb was presented in 8 intransitive sentences. In the neutral condition, half of the infants heard the transitive monologue, and half heard the intransitive monologue.

After a 7s interval, the practice item followed. Two events were presented: One showed a woman holding a shoe (shoe event), and the other showed a different woman holding a hat (hat event). The two events were first previewed one at a time for 6s, separated by a 3s blank-screen interval; each event preview was accompanied by a soundtrack labeling the object that the woman held (e.g., "She has a shoe. Look at this!"). The order of these previews was counterbalanced with sentence condition. Next, during a 4s blank-screen interval, the infants were prompted to look at the shoe event ("Who has a shoe?"). The two events then played simultaneously (6s), accompanied by sentences that matched the shoe event ("Who has a shoe? She has a shoe."). During another 4s blank-screen interval, infants were prompted to look at the hat event ("Who has a hat?"). Next,

the event pair was presented again in a second 6s trial, in which the accompanying audio matched the hat event ("Who has a hat? She has a hat.").

Following a 3s blank-screen interval, the critical test item was presented. The events were the same two novel events described in Experiment 1: a one-participant event and a two-participant event. As in Experiment 1, the soundtrack presented either the novel verb in two-noun transitive sentences (Transitive condition: "He's gorping him"), the novel verb in one-noun intransitive sentences (Intransitive condition: "He's gorping,"), or neutral sentences (Neutral condition: "What's happening?").

The timing of event presentation in the test item was similar to that in the practice item: The two events were first previewed one at a time for 6s each, separated by 3s blank-screen intervals. Each event was accompanied by neutral audio (e.g., "What's happening? Look here!"). Next, during an 8s blank-screen interval, infants heard the test sentence appropriate for their condition twice (e.g., "He's gonna gorp him! He's gonna gorp him!"). The two test events were then presented simultaneously in a 6s trial while infants heard two more test sentences (e.g., "He's gorping him. He's gorping him. See?"). In the subsequent 6s blank-screen interval, infants heard one more test sentence and a prompt (e.g., "He gorped him. Find gorping!"). Finally, the event pair was presented in a second 6s trial, accompanied by one additional test sentence and a prompt (e.g., "He's gorping him. Find gorping!"). The test trials were 6 rather than 8s long in Experiment 3 to shorten the amount of time the infants were asked to continuously attend to the combination of visual and auditory stimuli. In sum, the infants in the transitive and intransitive conditions heard the novel verb in its full syntactic context a total of 6 times during the test item, after the initial 8 times experienced in the monologue phase.

Coding

Visual fixations during the presentation of the practice and test items were coded as before. There was no effect of sentence condition on how long the infants spent looking away from the test events ($F<1$): The infants in the three sentence conditions again tended to look away about equally (transitive: $M = .51$, $se = .09$; intransitive: $M = .41$, $se = .07$; neutral: $M = .40$, $se = .07$). Thus, as before, we conducted our main analyses on the proportion of time infants spent looking at the two-participant event, out of time spent looking at either event, averaged across the two 6s test trials. Also as in the previous experiments, preliminary analyses of test-item performance revealed no interactions involving sentence condition and sex, or whether infants' performance in the practice trials or their vocabulary was above or below the median. Thus, the data were collapsed across these factors in subsequent analyses.

Results

As Table 1 shows, 19-month-olds' preference for the two-participant event was influenced by the sentence context. An ANOVA revealed a significant effect of sentence condition ($F(2,33) = 4.08$, $p = .026$) on infants' average proportion of looking-time to the two-participant event. Comparisons between sentence conditions revealed that infants in the transitive condition looked reliably longer at the two-participant event than did those in the intransitive ($t(22) = 2.38$, $p = .026$) and neutral conditions ($t(22) = 3.20$, $p = .004$). There was no significant difference between the intransitive and neutral conditions ($t(22) < 1$). Non-parametric Mann-Whitney tests provided converging results (transitive versus intransitive: $U = 42$, $p = .089$; transitive versus neutral: $U = 23$, $p = .004$; intransitive versus neutral: $U = 60$, $p > .5$).

Additional Results

An additional group of 19-month-old infants was tested using materials from Experiment 2, to (1) confirm the key difference between the transitive and intransitive conditions in 19-month-olds, and to (2) explore whether 19-month-olds are guided by structured conceptual representations in their use of number of nouns to interpret novel verbs, as were the 21-month-olds in Experiment 2. We used the materials from Experiment 2 to ask whether, like 21-month-olds, 19-month-olds prefer to map a novel transitive verb to a two-participant relational event, and not to any scene containing two people. In addition, we used the same practice trials from the main Experiment 3 ("Who has a hat" and "Who has a shoe", shown in Figure 5); these practice events do not depict 'bystander' objects or people and so could not prime or train the infants to ignore the extra person in the bystander test event.

24 19-month-old infants (Mean = 18.8 months, range 18.1 to 20.0; 12 girls and 12 boys) were recruited from the same population as described above. Half of the infants were assigned to the Transitive condition, and half were assigned to the Intransitive condition. Eight additional infants were tested and eliminated due to inattentiveness (3), because they spent less than 25% of the time in the practice items looking at the matching screen (1), because their proportion of looking-time to the two-participant test event was more than 3 SD from the mean of their condition (2), or because their faces were out of camera view during the test trials (2). The median productive vocabulary was 16, with a range from 4 to 51. According to parental report, 9 infants (Transitive: 2, Intransitive: 7) had "not yet" started combining words in production, while 14 combined words "sometimes" (Transitive: 10, Intransitive: 4) and 1 did so "often" (Intransitive).

The procedure and materials were identical to those described for the main Experiment 3 with three exceptions: (1) the novel events for the critical test item were replaced by the novel events from Experiment 2 (see Figure 4); thus, the infants watched a two-participant relational event and a bystander event; (2) the sentences containing the novel verb in the test item were changed to match these events, such that the pronouns in the sentences and the actors in the test events matched in gender (e.g., infants heard "She's gorping her" instead of "He's gorping him"); (3) the infants received three 6s trials instead of two. Given that the infants in this revised task were not previously exposed to the presence of a bystander in the practice trials, the additional test trial was intended to allow them more time to study these more complex test events and to integrate the linguistic and event information.

There was no effect of sentence condition on how long the infants spent looking away ($t < 1$): The infants in the two sentence conditions tended to look away about equally and equally briefly (transitive: $M = .56$, $se = .13$; intransitive: $M = .50$, $se = .11$). Preliminary analyses of test-item performance again revealed no interactions involving sentence condition and sex, or whether infants' practice-performance or vocabulary was above or below the median. Thus, the data were collapsed across these factors.

As Table 1 indicates, these additional data with 19-month-olds replicated the key result of Experiment 2 with 21-month-olds: When presented with a two-participant event and a bystander event, the 19-month-old infants in the transitive condition looked significantly longer at the two-participant event than did those in the intransitive condition ($t(22) = 2.81$, $p = .01$). This result was confirmed by a Mann-Whitney test ($U = 29$, $p = .012$).

Notice in Table 1 that the overall proportion of time infants spent looking at the two-participant event was fairly low, suggesting that the 19-month-olds had a baseline preference for the bystander event. This preference is not surprising; the addition of the bystander makes the event more complex and perhaps more interesting. This baseline preference is evident in 19-month-olds here, and not in 21-month-olds in Experiment 2, possibly because of the age difference between the two experiments, but also probably because the 19-month-olds had not been introduced to the addition of a bystander in the practice trials. Despite the overall preference towards the bystander event, the difference in their preference towards the two-participant event between transitive and intransitive conditions suggests that the 19-month-old infants (1) assigned different interpretations to the transitive and intransitive sentences containing the novel verb, and (2) interpreted the transitive novel verb as referring to a relational event involving two core participants, as opposed to any event in which two people were present.

Discussion

Experiment 3 reproduced the key results of Experiments 1 and 2 with younger infants, 19-month-olds. These findings support the prediction of the structure-mapping view that even very young infants should assign different interpretations to new transitive and intransitive verbs, as long as the number of nouns is informative. 19-month-olds who heard a novel verb in two-noun transitive sentences interpreted the verb as referring to an event involving two core participants, while those who heard the verb in one-noun intransitive sentences did not reach the same interpretation.

The results of Experiment 3 also extended those of previous experiments by showing that this ability to map the number of nouns in sentences to the number of

participants in an event did not depend on the presence of familiar-verb practice items that were similar to the novel-verb test item. It remains possible that infants' ability to do so could be supported by similar practice trials—such as those in Experiments 1 and 2—via priming of useful syntactic-semantic representations. However, our results suggest that infants of this age, prior to their participation in our experiment, already have some knowledge about the links between the number of nouns in sentences and the number of participant-roles and are guided by this knowledge in interpreting the novel verb in our task.

The use of syntactic cues by young children did not appear to depend on their vocabulary size. In none of the experiments was there a relationship between vocabulary level and children's use of sentence-structural cues. As mentioned in all experiments, there was no interaction of sentence condition and vocabulary group (above or below median) on test performance. 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: $\underline{r} = -.22$, $p > .4$, $\underline{N} = 16$; Experiment 2: $\underline{r} = .29$, $p > .4$, $\underline{N} = 8$; Experiment 3: $\underline{r} = .46$, $p = .14$, $\underline{N} = 12$; Experiment 3 additional results: $\underline{r} = .13$, $p > .7$, $\underline{N} = 12$). Perhaps most compellingly, the 19-month-olds tested in Experiment 3, like typical 19-month-olds, had small vocabularies. As we noted above, about half of them (28 out of 60, including those included in the Additional Results section) had not yet started combining words in their own 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 use simple sentence-structural cues to guide verb interpretation.

General discussion

Prior findings provide no indication that children younger than two years of age can use sentence-structural information to assign appropriately different interpretations to novel transitive and intransitive verbs (e.g., see Naigles & Swensen, 2007). In contrast, in two experiments presented here, 21- and 19-month-olds were able to assign different interpretations to novel transitive and intransitive verbs provided that the number of nouns in the sentence was informative. Hearing a novel verb in two-noun transitive sentences ("He's gorping him!") guided their attention to a two-participant event, while hearing the novel verb in one-noun intransitive sentences ("He's gorping!) did not. Moreover, children's interpretation of the accompanying novel verb was guided by structured conceptual representations: A novel transitive verb was interpreted as referring to a relational event involving two core participants, as opposed to any scene containing two people. Finally, the children were able to map the number of nouns in sentences to participant-roles in events in our task without exposure to familiar-verb practice items that were similar to the test item.

The present findings add to previous evidence that children of two to five years of age engage in structure-guided interpretation of novel transitive and intransitive verbs (Fernandes et al., 2006; Fisher et al., 1994; Fisher, 1996; 2002a; Naigles, 1990; 1996; Naigles & Kako, 1993). The current findings extend this prior research in two keys ways. First, this is the first evidence that children younger than two years of age use aspects of

syntactic structure to assign appropriately different interpretations to novel transitive and intransitive verbs. Prior evidence pointed to persistent failures to do so by children younger than two years (see Naigles & Swensen, 2007). We proposed that the stimulus sentences in the previous experiments, by putting the number of nouns in conflict with the true syntactic structure of the sentence, masked infants' ability to differentiate novel transitive and intransitive verbs. When the stimuli were modified so that the number of nouns in sentences was informative, we were able to find sensitivity to sentence structure in much younger children. Second, the current findings show that by 19 months, sensitivity to simple aspects of sentence structure need not depend on learning or priming within the experiment. Children do not need to experience familiar-verb practice trials that are highly similar to the novel-verb test trials in order to show sensitivity to sentence structure in novel-verb interpretation.

The present findings provide support for the structure-mapping account of syntactic bootstrapping by shedding light on the kinds of sentence and event representations young children invoke in structure-guided learning. The key assumptions of the structure-mapping account are that children are biased towards one-to-one mapping between noun-phrases in sentences and semantic arguments of verbs, and that this process works because children's linguistic and conceptual representations share structural similarity. These assumptions generate the prediction that the number of nouns should serve as an early cue to the verb's semantic predicate-argument structure, as well as the prediction that children's use of this simple cue should be constrained by their structured conceptual representations of events. The present findings confirm these predictions, suggesting one way in which syntactic bootstrapping can start: Young

children have access to certain core, non-arbitrary relationships between syntax and semantics, which serve as constraints on how they learn verbs and grammar, even in the very beginnings of multi-word sentence comprehension.

The shallow analysis of sentences proposed by the structure-mapping account provides very abstract information about the verb's meaning. It simply indicates the number of participant-roles involved in the verb's meaning, relevant to what may be called the verbs' semantic structure (Grimshaw, 1993). However, a useful consequence of such a shallow analysis is that children need not possess sophisticated syntactic knowledge in order to use the sentence structure to interpret a new verb. Upon hearing sentences such as "The duck is gorping the bunny," children can infer something about the meaning of 'gorp' without already knowing the syntactic notions of subject and object (e.g., '"duck" takes the subject position'), or the links between these grammatical positions and semantic roles (e.g., 'If "duck" takes the subject position, then it must be an agent').

Another useful consequence of shallow sentence representations, as predicted by the structure-mapping account, is that the number of nouns should guide not only verb learning but also the learning of any argument-taking predicate term. Support for this prediction comes from recent evidence that two-year-olds make use of the number of nouns in sentences to learn new prepositions (Fisher, Klinger, & Song, 2006): Children interpret a novel word embedded in a sentence with two nouns (e.g., "This is acorp my box") as referring to a spatial relation, while they interpreted a similar sounding novel word that was not followed by a noun-phrase ("This is a corp") as referring to an object kind. This represents an advantage of the structure-mapping account, that mapping the

number of nouns to the number of arguments provides a simple constraint that is useful for learning the argument-taking properties of predicate terms in general.

By the same token, the simplicity of shallow sentence representations can lead to some pitfalls. Having described the non-arbitrariness of the relationship between the number of noun phrases in sentences and the number of arguments, we want to point out that the number of nouns is a probabilistic indicator of the semantic-argument structure of verbs. Noun phrases in a sentence and arguments of the verb are not the same thing. First, sentences can contain more noun phrases than there are arguments of the main verb. The extra noun phrases can be adjuncts, linked into the sentences by predicate terms other than the sentence's main verb: In (3a) on the table is an argument of put, expressing the destination of the putting action; in (3b) the same phrase is not an argument of see, but an adjunct specifying which book was seen. In (4) the two noun phrases are not two distinct arguments of the verb sleep; rather, they are conjoined as a single argument of the verb. Second, sentences can have fewer noun phrases than there are arguments of the main verb. Passivized (5) and imperative (6) sentences, for examples, do not spell out all the arguments of the verb. Such phenomena ensure that the number of noun phrases does not always map neatly onto the number of verb arguments in individual sentences in casual speech. This presents a potential challenge to syntactic bootstrapping in that the number of nouns in a single sentence is not a perfect cue to the predicate-argument structure of its main verb.

(3) a. John put the book on the table.

b. John saw the book on the table.

(4) The mother and the baby are sleeping.

(5) Bill was scolded.

(6) Finish your peas!

For the older child or the adult, knowledge of the grammar can help them appropriately interpret these sentences. Armed with knowledge of the imperative structure in English, for example, an experienced English listener knows that the sentence in (6) is intended to express an event involving two participant-roles, including the agent-role, which is not specified in the sentence. Similarly, knowledge that the conjunction 'and' links the 'mother' and 'baby' in (4) into a single noun-phrase guides the listener in interpreting such sentences. For the young learner who does not yet have sophisticated knowledge of the native language's grammar, however, this imperfect mapping between nouns in sentences and arguments of the main verb raises potential problems. The set of nouns in a single sentence is far from an infallible cue to the semantic predicate-argument structure of the main verb in the sentence.

As a result, the structure-mapping account predicts characteristic errors in early sentence interpretation, when the number of nouns in a sentence containing a new verb provides misleading information about the verb's true number of arguments. If children are operating strictly on the counting-the-nouns strategy, without consulting or having acquired knowledge of language-specific constructions or more complex syntactic structures, young children should make mistakes (Connor, et al., 2008; Gertner & Fisher, 2009). One example of such an error has been confirmed by recent work showing that 21-month-olds were fooled by the number of nouns into interpreting a two-noun intransitive sentence (e.g., "The girl and the boy are gorping!") as a transitive sentence conveying agent-patient role information (Gertner & Fisher, 2009). Work on adult sentence

processing suggests that the influence of shallow representations of syntax is not limited to children: Even adults sometimes err in applying a canonical sentence schema to non-canonical sentences (Ferreira, 2003). Just like adults, children are influenced by shallow syntactic representations in their sentence interpretation and may at times be misled by their initial syntactic misanalysis based on these representations.

Aside from learning about the grammar, the older child or the adult is also guided by prior knowledge of the combinatorial behavior of verbs to compute the correct syntactic and semantic structure for sentences such as (1) through (4) (e.g., Snedeker & Trueswell, 2004). Upon hearing (1b), the experienced English listener knows that see is very unlikely to take 'on the table' as an argument. Discussions of syntactic bootstrapping have proposed that young learners can escape from this difficulty in just the same way – by gathering syntactic information across many sentences to estimate the argument-structure biases of each verb (e.g., Fisher & Gleitman, 2002). Analyses of child-directed speech in English show that collections of ordinary sentences provide strong probabilistic information about verbs' argument structures (Brent, 1994; Naigles & Hoff-Ginsberg, 1995). Experimental investigations showing that toddlers can gather combinatorial information about a novel verb over instances and use that information to interpret the verb in an uninformative structure suggest that children can make use of the voluminous data in the input speech to estimate the argument-taking behavior of verbs (Scott & Fisher, 2009; Yuan & Fisher, 2009; Chapter 4). Thus, given the probabilistic information in the input and children's potential ability to make use of it to approximate verbs' argument structures, even simple representations would be powerful enough to drive learning.

While the present findings suggest an early use of abstract sentence structure in children's verb learning, this does not preclude the possibility that children acquire constructions or language-specific syntax, as they must and do. It has been demonstrated in numerous studies that children's sentence processing is influenced by their knowledge of English word order, adjective morphology, noun phrase morphology, and so on (e.g., Gertner, Fisher, & Eisengart, 2006; Waxman & Booth, 2001; Santelmann & Jusczyk, 1998; Shady, Gerken & Jusczyk, 1995). Moreover, children would have to engage in something like the construction-based learning sketched in the Introduction to learn the more refined verb subclasses that alternate in particular ways in their input language (e.g., Pinker, 1989). Our hypothesis, however, is that without having to rely on language-specific syntactic knowledge, young children can be guided by some unlearned constraints to start using sentence-structure information in verb learning. The current evidence that young children succeed in using simple structural cues to interpret novel verbs provide some supporting evidence for this hypothesis. This has implications for one way in which children's abstract representations may interact with their language-specific learning. Children may begin using sentence structure for verb learning before learning much about the language-specific details of the syntax. Moreover, having shallow but abstract representations in place may constrain or accelerate language-specific learning. For example, the ability to represent sentences in terms of the number of nouns may facilitate the learning of the word order of transitive sentences.

Could the construction-based learning account explain our data? In principle it could, simply by proposing that by 19 months children have accomplished enough verb-by-verb learning to generate an abstract representation of the English transitive

construction. We consider this unlikely, given the small vocabularies of 19-month-olds, however (e.g., Caselli et al., 1999). Further evidence that the one-to-one correspondence between noun phrases in sentences and semantic arguments of verbs does not have to be learned comes from investigations of verb learning in languages other than English, where the noun-phrase number is not as reliable a cue to the verbs' underlying argument structure. In many languages, such as Mandarin Chinese, noun phrases in sentences can be, and frequently are, omitted if they can be recovered in the discourse context (Li & Thompson, 1981; Wang et al., 1992). This could make the relationship between noun-phrase number and verb-argument number much less apparent in the linguistic input. Despite the less reliable information about the relationship between syntax and semantics in the input, however, Mandarin learners, just like their English-speaking counterparts, rely on noun-phrase number as a cue to verbs' argument structures (Lee & Naigles, 2008; Chapter 3). Similarly, learners of Kannada rely more strongly on noun-phrase number than on language-specific causative morphology in assigning a causal interpretation to sentences, even though in Kannada noun-phrase number is less reliable than causative morphology as an indicator of verbs' causative meaning (Lidz et al., 2003). These findings are consistent with the present arguments that the number of nouns is an intrinsically meaningful cue to young children. That is, children may not have to learn from the input language how to interpret it as a cue to verbs' argument structures.

The present results provide the first evidence that children younger than 2 years are guided by sentence-structural cues in interpreting novel transitive and intransitive verbs. Young children possess sentence and conceptual representations that share structural similarity, and assume that each noun-phrase in the sentence assumes a

participant-role. Such early biases serve as precursors to knowledge of syntax-semantics links, allowing young children to embark on structure-guided learning.

CHAPTER 3

MANDARIN-SPEAKING 2-YEAR-OLDS USE SIMPLE SYNTACTIC CUES IN INTERPRETING NOVEL VERBS

The syntactic bootstrapping hypothesis postulates that children use information about the sentence structure to learn aspects of a new verb's meaning (Gleitman, 1990). Evidence for syntactic bootstrapping comes from many studies showing that children between 2 and 5 years of age assign different interpretations to novel verbs presented in different syntactic contexts (e.g., Fisher, 1996; 2002a; Fisher et al., 1994; Naigles, 1990, 1996; Naigles & Kako, 1993; Yuan, Fisher, Snedeker, & Gertner, in prep.). The vast majority of the evidence for syntactic bootstrapping, however, came from studies conducted with English-speaking children. This raises an important question: How universal is syntactic bootstrapping? Is it a fundamental part of verb learning in all languages?

Syntactic bootstrapping works because there are systematic relationships between the sentence structures verbs occur in and their semantic predicate-argument structure (e.g., Bloom, 1970; Fillmore, 1968; Fisher, Gleitman, & Gleitman, 1991; Gleitman, 1990; Goldberg, 1995; Grimshaw, 1994; Levin & Rappaport Hovav, 2005; Pinker, 1989). For example, transitive verbs take two noun-phrase arguments (e.g., "He tickled him") and describe events that involve two core participants (tickler, ticklee). In contrast, intransitive verbs take one noun-phrase argument (e.g., "He laughed") and describe events that involve one core participant (laugher). Many studies have shown that English-speaking children use the number of noun phrases in the sentence as a cue to verbs'

semantic predicate-argument structure. For example, in experiments by Yuan et al. (in prep.), 19- and 21-month-olds were shown two novel events side by side, accompanied by a novel verb. One event showed a two-participant causal event (one boy bending another boy forward and back), and the other showed a one-participant solo event (one boy making "jumping-jack" arm motions). Children who heard the novel verb in transitive sentences (e.g., "He's gorping him!") looked longer at the two-participant event than did children who heard the novel verb in intransitive sentences ("He's gorping!"). These and other results suggest that young children are sensitive to the close relationship between the number of noun phrases accompanying a verb and the number of core participants involved in that verb's meaning. In this paper we examined Mandarin-learning toddlers' sensitivity to this intimate relationship between noun-phrase number and participant number.

Investigation of syntactic bootstrapping in languages other than English is crucial because English has some properties that might make syntactic bootstrapping particularly helpful. Many languages, such as Japanese and Mandarin Chinese, permit noun-phrase arguments to be omitted when they are recoverable. English permits very little argument omission. In English, even noun-phrase arguments that are fully recoverable in the discourse setting are expressed by overt elements in sentences. In describing an event that involves taking, for example, both core participants—the taker and the entity taken—must be expressed in the sentence, as in (1). Subjects are omitted in English only in very limited contexts (e.g., Schmerling, 1972), and analyses of English child-directed speech indicate that 85% of the uses of transitive verbs (e.g., take, push) involve an overt post-verbal noun phrase whereas only 1% of the uses of intransitive verbs (e.g., go, jump) do

so (Naigles & Hoff-Ginsberg, 1995).[1] Thus, in English, the number of overt noun phrases reflects the number of the verb's arguments fairly clearly and serves as a good cue to verbs' semantic predicate-argument structure.

(1) Q: What happened to that book?

A: He took it away.

(2) Q: Neiben shu ne?

that book QUESTION-particle

What happened to that book?

A: Ta nazou le.

he take-away PAST-particle

He took (it) away.

In many languages, however, the relationship between noun-phrase number and a verb's number of underlying arguments is less straightforward. For example, Mandarin Chinese allows subjects and objects to be omitted in appropriate discourse contexts (Li & Thompson, 1981). Roughly speaking, Mandarin speakers omit noun phrases altogether in many of the contexts where English speakers would use pronouns. In describing the above taking event, for example, it is acceptable to omit mention of the taken entity if its identity is recoverable in the discourse context, as in (2).

Such argument omission is frequent in spoken Mandarin, including child-directed speech (Lee & Naigles, 2005; Wang et al., 1992). Analyses of child-directed Mandarin by Lee and Naigles (2005) indicated that only about 40% of transitive verb uses involved an overt post-verbal noun phrase, while 17% of intransitive verb uses had post-verbal

[1] The uses of transitive verbs that do not involve an overt post-verbal noun phrase (the remaining 15 %) include instances in which the direct object is moved but not omitted (e.g., "What kind of juice do you want?") and instances of idioms (e.g., "take forever").

noun phrases. Thus, the presence of a post-verbal noun phrase is still a useful cue to identify transitive verbs in Mandarin, but noun-phrase number clearly does not align as reliably with the verb's underlying number of arguments as it does in English. Similar findings emerge from analyses of child-directed Japanese (Rispoli, 1995) and Hindi (Narasimhan, Budwig & Murty, 2005), languages that both permit discourse-governed omission of subject and object noun phrases.

Such phenomena raise questions about the cross-linguistic usefulness of simple syntactic-structure cues to verb meaning (e.g., Rispoli, 1995; Bowerman & Brown, 2007). Do learners of languages such as Mandarin use verb transitivity to guide verb interpretation? In particular, given that noun phrases are often missing in the input they receive, do Mandarin-speaking children interpret the number of noun phrases in a sentence as information about the semantic predicate-argument structure of its verb? Two theoretical approaches make contrasting predictions on this question. We will discuss each in turn.

The construction-based learning account proposes that children learn language-specific constructions via considerable prior learning of individual verbs (Goldberg, 1999; Tomasello, 2000). On this account, children begin learning verbs without the aid of syntactic bootstrapping. They learn about the lexical-syntactic environments and the meanings of individual verbs. Knowledge about each verb constitutes a verb-specific construction, a form-meaning pairing unique to that verb, with no consequences for the usage or interpretation of other verbs. After accumulating many such verb-specific constructions, children begin to detect abstract similarities in form and meaning among verbs. This step relies on analogical comparison of distinct verbs' relational structures.

For example, English-learning children gradually build an abstract transitive construction, encompassing verbs that occur in the Noun-phrase—Verb—Noun-phrase structure and that describe two-participant relationships.

On this account, children must learn to interpret the number of noun phrases in a sentence as information about the verb's likely number of participant-roles, as a result of acquiring abstract language-specific constructions. Because this learning depends on regularities in the input, this account readily predicts developmental differences across languages in children's ability to use noun-phrase number as a cue to verb meaning. Frequent argument omission, for example, might delay children's reliance on the number of noun phrases by introducing noise into the relevant input regularities on two levels. First, missing noun phrases could add noise to the syntactic profile of each individual verb, making it difficult for a child to determine each verb's true transitivity (Rispoli, 1989). Second, this difficulty in identifying each verb's transitivity could make it difficult for Mandarin learners to form generalizations across verbs concerning the relationship between noun-phrase number and participant-role number (Lidz, Gleitman, & Gleitman, 2003). As a result, the construction account predicts that children learning Mandarin might take longer to learn to use the number of noun phrases to interpret new verbs than would English-learning children, because the number of noun phrases is a much noisier cue to verbs' predicate-argument structure.

In contrast, the structure-mapping account makes a very different prediction. This account proposes that children possess an intrinsic bias towards one-to-one mapping between noun phrases in sentences and participant-roles (Fisher, 1996; Lidz et al., 2003). On this view, children need not learn that the number of noun phrases each verb occurs

with maps onto the number of participant-roles implied by its meaning. One line of evidence for this unlearned bias comes from the study of Home Sign (e.g., Goldin-Meadow, 2003): Deaf children, deprived of linguistic exposure, spontaneously created signing systems in which verb-like gestures were accompanied by a predictable number of noun-like gestures (e.g., eat with two, sleep with one). This suggests a natural tendency for children to align noun phrases in sentences one-to-one with a verb's core participants, at least in their own productions. The structure-mapping account strongly predicts that sensitivity to noun-phrase number in verb learning should occur early, despite cross-language differences in argument omission. Regardless of how noisy the relationship between noun-phrase number and participant-role number is in the input, when Mandarin speakers encounter a new verb appearing with a known number of noun phrases, the structure-mapping account predicts that they should know how to interpret it.

Three prior experimental reports yield evidence that children learning languages other than English use syntactic evidence to alter their interpretations of familiar verbs (Göksun, Küntay, & Naigles, 2008; Lee & Naigles, 2008; Lidz et al., 2003). All three experiments tested preschoolers learning languages in which noun-phrase number is a relatively noisy cue to a verb's underlying meaning due to frequent argument omission; in all three experiments, preschoolers showed sensitivity to the number of overt noun phrases in adapting the meaning of familiar verbs. Children acted out familiar transitive or intransitive verbs presented either in fully grammatical sentences ("The lion goes"; "The lion takes the pig"), or in sentences with an added or missing noun-phrase ("*The pig goes the lion"; "*The lion takes"). Most relevant to the current study, Lee and Naigles (2008) found that Mandarin-speaking 2.5- and 3.5-year-olds interpreted familiar verbs in

accordance with the number of noun phrases in the sentence: For example, when presented with an intransitive verb in a two-noun-phrase, transitive frame (e.g., "*The pig goes the lion"), Mandarin-speaking children enacted a two-participant causal interpretation (e.g., the pig makes the lion go). When presented with a transitive verb in a one-noun-phrase intransitive frame (e.g., "*The dog brings"), children more often enacted a one-participant event (e.g., the dog goes) than when the verb was presented in a two-noun-phrase, transitive frame. Similarly, 3-year-old Kannada speakers more often enacted causal interpretations of sentences containing two noun phrases than of sentences containing one noun phrase (Lidz et al., 2003). Interestingly, the young Kannada speakers relied more heavily on noun-phrase number than on the presence of a causative morpheme in arriving at a causal interpretation, even though in Kannada the number of noun phrases is arguably a less reliable indicator of causative meaning than is causative morphology. Finally, Turkish-speaking preschoolers and kindergarteners were also influenced by noun-phrase number in interpreting sentences with familiar verbs, despite frequent omission of noun phrases in Turkish (Göksun et al., 2008). Though Göksun et al. reported smaller effects of the number of noun phrases in Turkish learners than in English learners and speculated that this might be due to the lesser reliability of noun-phrase number as a cue to verb meaning in Turkish, the Turkish children showed greater sensitivity to noun-phrase number than did the Turkish adults, suggesting an early reliance on the fundamental relationship between noun-phrase number and verb predicate-argument structure. Taken together, these findings indicate a widespread sensitivity to the number of noun phrases in interpreting familiar verbs. This sensitivity is not limited to languages such as English, in which noun-phrase number is a highly

reliable cue. These findings therefore support the predictions of the structure-mapping account.

These prior studies examined children's use of sentence structure to extend the meanings of verbs they already knew. Can Mandarin-speaking toddlers use verb transitivity to assign interpretations to unknown verbs? Mandarin-speaking 5-year-olds were shown to be sensitive to verb transitivity in interpreting novel verbs (Cheung, 1998): Children generated appropriately different paraphrases for made-up verbs presented in transitive versus intransitive sentences. The current study builds on the prior findings in two ways. First, we asked whether Mandarin-speaking toddlers use the number of noun phrases to assign appropriate interpretations to unknown verbs. Second, we extended this investigation to younger children, 24-month-olds. Children at this age have been shown to use syntactic evidence in novel verb learning in English (Naigles, 1990). Will Mandarin-speaking 2-year-olds do the same?

Mandarin-speaking 2-year-olds in Taiwan were tested in the current study. The task was similar to the task used by Yuan et al. (in prep.) with English-speaking toddlers. During the critical test phase, the children were shown a pair of novel events side by side (see Figure 6): One showed a two-participant causal event (one boy bending another boy forward and back), and the other showed a one-participant solo event (one boy making arm motions as in jumping-jacks). At the same time, the children heard either a novel verb (fo1[2]) in transitive sentences (Transitive condition: "Ta1 zai4 fo1 ta1/He's foing him!"), a novel verb in one-noun intransitive sentences (Intransitive condition: "Ta1 zai4 fo1/He's foing!"), or neutral sentences without the novel verb (Control: "Ni3 kan4dao4le she3me/"What do you see?").

[2] The number after each Chinese word indicates the tone of the word.

For half of the children, an initial listening phase preceded the experiment proper. During this listening phase, the children watched dialogues between two actors, using the novel verb in multiple sentences. The sentences were transitive if the children were in the Transitive condition (e.g., "Hong-Hong is gonna fo puppy!"), or intransitive if the children were in the Intransitive condition (e.g., "Hong Hong is gonna fo!"). Among children who were in the Neutral condition, half received the transitive dialogues and the other half received the intransitive dialogues. This listening phase was designed to provide the children with initial exposure to the verb and its syntactic properties before testing them on interpretation of the verb. Half of the children received this listening phase (With-listening-phase condition), and half did not (No-listening-phase condition). We introduced this manipulation based on the following reasoning. Young children's early productions reveal sensitivity to the frequency of argument omission in their input language (Valian, 1991; Kim, 2000). It is possible that Mandarin learners at 2 years have some knowledge that arguments can be omitted from sentences and, as a result, are uncertain of a new verb's syntactic profile if only briefly exposed to it in a few sentences. Thus, in a task like that of Yuan et al. (in prep) in which the encounter with the novel verb is brief, we speculated that Mandarin learners could appear insensitive to the number of nouns in novel-verb interpretation, not because of an inability to infer participant-role number from the number of nouns phrases, but because of their uncertainty about the number of noun phrases the novel verb typically occurs with. We therefore provided half the children with additional exposure to the verb via the listening phase at the beginning of the experiment to make clear to the children the syntactic profile of the unknown verb.

If the Mandarin-speaking 2-year-olds, like their English-speaking counterparts, can use the number of noun phrases to assign interpretations to the novel transitive and intransitive verbs, then children in the Transitive condition should look longer at the two-participant event in the test phase than would children in the Intransitive and Control conditions. Children in the Intransitive condition, in contrast, should not have a strong preference towards either test event, because the one-noun-phrase intransitive sentence could plausibly refer to either the one-participant event or to a component of the two-participant event. This finding would suggest that the lesser reliability of the set of noun phrases in the sentence as evidence for the argument-taking properties of the verb has no consequences for Mandarin learners' ability to use the number of noun phrases. Such a finding would be more consistent with the structure-mapping view that children need not learn that noun-phrase number maps onto event-participant structure, than with the construction-based learning view.

Experiment 4

Method

Participants

Sixty 2-year-olds (Mean 23.9 months; range 21.7-26.3; 30 girls and 30 boys), all native Mandarin speakers, participated in a university lab in Taipei, Taiwan. Six additional children were not included due to inattentiveness (2), refusal to watch the video (1), or experimenter error (3). Children's productive vocabularies, measured by the Chinese Communicative Development Inventory Mandarin version (CCDI; Tardif et al., 2002), ranged from 6 to 759 (median 359).

Half of the children (Mean 24.1 months; 15 girls and 15 boys) were assigned to the Listening-phase condition, and half (Mean 23.7 months; 15 girls and 15 boys) were assigned to the No-listening-phase condition. Within each of these two conditions, the children were assigned to one of the three sentence conditions: Transitive, Intransitive, or Control.

Apparatus

Children sat on a parent's lap, facing a 40" x 30" projection screen about 53" away. The videos consisted of two video images (16" x 14"), 5" apart, displayed side by side. For those in the With-listening-phase condition, the videos also included single video images, for the listening phase, displayed on the whole screen. For all the children, audio played from a central speaker. A hidden camera centered beneath the projection screen recorded children's eye-movements. Parents wore opaque glasses.

Materials and Procedure

The stimuli were color videos of people performing simple actions, accompanied by a soundtrack recorded by a female native Mandarin speaker. These action videos were combined into synchronized pairs that played side-by-side in two video 'windows' about 16" by 14", 5" apart. The videos presented in the Listening phase (presented only to children in the Listening-phase condition) depicted two women talking to each other. These dialogue videos were presented as one large image filling the projection screen.

The procedure for the Listening-phase condition consisted of three parts in the following order: the novel-verb listening phase, familiar-verb practice trials, and novel-verb test phase.

In the novel-verb listening phase, a novel verb (fo1) was presented in 8 sentences,

spoken by two native Mandarin speakers in a videotaped conversation (see Figure 6). Children in the Transitive condition heard the novel verb used in only transitive sentences (e.g., "Hong-Hong is gonna fo puppy!"), while children in the Intransitive condition heard the verb in only 1-noun intransitive sentences (e.g., "Hong-Hong is gonna fo!"). The transitive and intransitive sentences were identical except for the presence or absence of the nouns in direct object position. Within the Control condition of the Listening-phase group, half of the children heard the transitive dialogues, and half heard the intransitive dialogues.

Next, the familiar-verb practice trials followed. Two familiar verbs (tiao4/jump, wei4/feed) were presented, each in two 8s trials. For the first verb (tiao4/jump), two video events played (8s) simultaneously, and children heard "He's jumping... Where's jumping?". The target video showed a male actor jumping, while the distracter video showed a different male actor sleeping. Following a blank-screen interval (6s), the test events were presented again (8s), with further prompts to "Find jumping".

After a 7s interval, the second familiar verb (tiao4/feed) was tested in the same manner. The target event showed one female actor feeding another; the distracter showed two different female actors, one tickling the other. Children heard "She's feeding her! Find feeding!". These familiar-verb sequences served to familiarize children with the task, and to teach them that one of the two videos presented in each pair matched the soundtrack.

Finally, after another 7s interval, the novel verb was tested in the same manner (see Figure 6), with the exception that there were three 8s trials rather than two. Children watched two simultaneously-presented novel events: one showed a two-participant causal

event, and the other showed a one-participant solo event. At the same time, children heard either the novel verb in transitive sentences ("He's foing him!", Transitive condition), the novel verb in 1-noun intransitive sentences ("He's foing!", Intransitive condition), or neutral sentences without the novel verb ("What do you see?", Control condition). For the Transitive and Intransitive conditions, the novel verb was presented a total of 8 times in the three trials. Side of presentation of the test events was counterbalanced with sentence condition.

For the No-listening-phase condition, the procedure was identical except that the initial novel-verb listening phase was omitted.

Coding

We coded where children looked (left, right, away) during the 8s test trials of the novel-verb test phase, frame-by-frame from silent video. Reliability was assessed for 12 children; coders agreed on 96% of video frames. Trials were treated as missing (n=2) if the child looked away for more than half of the 8s trial.

To determine whether children in different conditions spent different amounts of time looking away from the two test videos during the novel-verb test phase, we conducted a 2 (Listening: Listening-phase or No-listening-phase) by 3 (Sentence: Transitive, Intransitive, Control) analysis of variance (ANOVA) of away looking-times (averaged across the three 8s trials). There were no reliable main effects or interaction (F's<1), suggesting that the children in all conditions tended to look away about equally, and equally briefly, during the novel-verb test phase (Listening-phase—transitive: M = .56, se = .17; intransitive: M = .57, se = .12; control: M = .42, se = .16; No-listening-phase—transitive: M = .53, se = .12; intransitive: M = .42, se = .12; neutral: M = .53, se =

.10). Given the uniformity in time spent looking away, we conducted our analyses on a single measure: the proportion of time spent looking at the two-participant event, out of total time spent looking at either the two- or one-participant event. The average of this proportion across the three test trials was our dependent measure. Analyses based on absolute looking-times to the two- and one-participant event revealed patterns of significant effects similar to the main analyses reported below.

Preliminary analyses of novel-verb test performance revealed no interactions of listening-phase and sentence condition with sex, whether children's vocabulary was above or below the median, or whether children's looking-time to the matching screens in the practice trials was above or below the median (F's<1). The data were therefore collapsed across sex, vocabulary group and practice-performance group in subsequent analyses.

Results and discussion

As shown in Table 2, children's visual preferences during the novel-verb test phase were influenced by the sentence context: Those 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 who heard neutral sentences without the novel verb. This pattern held in both the Listening-phase and No-listening-phase conditions. These observations were confirmed by a 2 (Listening: Listening-phase or No-listening-phase) by 3 (Sentence: Transitive, Intransitive, Control) ANOVA, revealing a significant effect of sentence condition ($F(2,54) = 5.77$, $p = .005$), and no other reliable effects, on the average proportion of looking-time to the two-participant event.

Planned comparisons confirmed that children in the Transitive condition looked

significantly longer at the two-participant test event than did those in the Intransitive ($t(38) = 3.26$, $p = .002$) and Control conditions ($t(38) = 3.09$, $p = .004$); the Intransitive and Control conditions did not differ from one another ($t(38) < 1$). These effects held within each Listening-phase condition: Children in the Transitive condition looked significantly longer at the two-participant test event than did those in the Intransitive (Listening-phase: $t(18) = 2.15$, $p = .045$; No-listening-phase: $t(18) = 2.38$, $p = .028$) and Control conditions (Listening-phase: $t(18) = 2.65$, $p = .016$; No-listening-phase: $t(18) = 2.14$, $p = .047$), but the looking preferences of children in the Intransitive and Control conditions did not differ (t's$(18) < 1$). Non-parametric Mann-Whitney tests yielded similar results (Overall—transitive versus intransitive: $U = 97$, $p = .005$; transitive versus neutral: $U = 89$, $p = .002$; intransitive versus neutral: $U = 179$, $p > .5$; Listening-phase—transitive versus intransitive: $U = 24$, $p = .052$; transitive versus neutral: $U = 20$, $p = .023$; intransitive versus neutral: $U = 47$, $p > .8$; No-listening-phase—transitive versus intransitive: $U = 21$, $p = .029$; transitive versus neutral: $U = 24$, $p = .052$; intransitive versus neutral: $U = 44$, $p > .6$).

These results suggest that, with or without prior experience with the verb and its syntactic properties, 2-year-old Mandarin-speaking children used the number of noun phrases in the sentence to interpret the novel verb. A verb that occurred with two noun phrases was interpreted by the children to refer to an event that involved two participants, whereas a verb that occurred with one noun phrase was not assigned this interpretation.

General discussion

In the current study, Mandarin-speaking two-year-olds used the number of noun

phrases in the sentence to interpret a novel verb. Children who heard the novel verb in two-noun-phrase, transitive sentences looked longer at the two-participant event than did those who heard the novel verb in one-noun-phrase intransitive sentences, or those who heard neutral sentences without a novel verb. They did so either with or without prior exposure to the verb and its syntactic properties in an initial listening phase. Thus, like their English-speaking counterparts (Yuan et al., in prep.; Chapter 2), young Mandarin learners use sentence-structural information in interpreting new verbs.

The current findings add to the prior evidence of syntactic bootstrapping in languages other than English (Lee & Naigles, 2008; Göksun et al., 2008; Lidz et al., 2003; Cheung, 1998) in suggesting that syntactic bootstrapping is a fundamental part of verb learning in languages other than English. Despite input that demonstrably suggests a less reliable relationship between noun-phrase number and verb argument structure, young Mandarin learners still show sensitivity to the number of noun phrases in interpreting a new verb. This is consistent with the assumption of the structure-mapping account that young learners are guided by a one-to-one mapping bias between the noun phrases in the sentence and a verb's semantic arguments, regardless of language-specific characteristics regarding argument omission. The current findings extend prior findings by testing very young learners of Mandarin—2-year-olds—and by testing their sensitivity to the number of noun-phrases in interpreting brand new verbs.

The current findings would be unexpected on an account of syntactic bootstrapping that is based entirely on construction learning. The less reliable relationship between noun-phrase number and verb argument structure in Mandarin should make it more difficult for children to learn to use the number of noun phrases as a cue to verb

meaning. In principle, the construction-based learning account could accommodate the present findings by arguing that by two years of age, these Mandarin-speaking children have already sorted out, amidst the noise, enough individual verbs to learn the general relationship between noun-phrase number and verbs' argument structure. However, this would require a substantial revision of the construction-based learning account, given the claim of this account that it is not until sometime in the third year of life that English learners possess an abstract representation of the transitive construction and use it productively (Tomasello, 2000; Akhtar & Tomasello, 1997).

While we and others have portrayed argument-dropping languages such as Mandarin as a special test case for syntactic bootstrapping, across languages—even in English—there are a variety of sources of noise in the relationship between noun phrases in the sentence and semantic arguments of a verb. Some verbs alternate between different structures, as in (3), thus appearing with different numbers of noun phrases on different occasions. Certain special constructions may have a reduced (4a) or increased (4b) number of noun phrases, relative to typical estimates of the verb's semantic arguments (Goldberg, 2004). Finally, adjunct phrases routinely introduce elements into sentences that are not arguments of the verb. In (5a), on the table is an argument of put, expressing the destination of the putting action; in (5b), the same phrase is not an argument of see, but an adjunct specifying which book was seen. We cited analyses of child-directed speech in the Introduction showing that argument omission in Mandarin makes the data provided to Mandarin learners noisier in relevant regards than are the data provided to English learners. Nevertheless, the lesson of the present examples is that individual sentences in casual speech in any language cannot be taken as unassailable evidence of

their verbs' argument structures, even for English learners. This does not make syntactic bootstrapping less useful, however, if children can gather data across utterances to derive the intended argument structure of an individual verb (Fisher & Gleitman, 2002). Recent findings indicate that toddlers can gather combinatorial information about a novel verb over sentences and use it to interpret the verb in an uninformative structure, suggesting that children are equipped to estimate the argument-taking behavior of verbs across utterances (Scott & Fisher, 2009; Yuan & Fisher, 2009). While an estimate of the number of noun phrases may need to be sorted out for each individual verb, the structure-mapping view argues that children do not have to learn the semantic consequences of the number of noun phrases.

(3) a. She dusted the lamp.

b. She dusted.

(4) a. The tiger killed again. (deprofiled object construction; Goldberg, 2006)

b. Pat laughed a hearty laugh. (cognate object construction; Goldberg, 2006)

(5) a. John put the book on the table.

b. John saw the book on the table.

While the current findings suggest that young Mandarin learners find syntactic cues informative in interpreting new verbs, they do not suggest that Mandarin learners (or learners of any language) rely exclusively on syntactic information for learning about the argument structure of a new verb. As discussed previously, the omission of noun phrases in Mandarin typically occurs when the referent can be understood from the discourse or pragmatic contexts (Li & Thompson, 1981). Non-syntactic contexts as such can serve as

an information source for learning verb argument structure (Allen, 2000). Analyses of children's speech in Cantonese, Korean, Japanese and Hindi indicate that young children are sensitive to discourse and pragmatic factors in their own choices of which arguments to omit (Lan, 1999; Clancy, 2003; Rispoli, 1992; Narasimhan et al., 2005). For example, children may omit a noun phrase once the referent has been established as the topic in the discourse or when the referent is readily available in the extra-linguistic context. In principle, the same sensitivity to discourse/pragmatic contexts could be extended to interpreting potential omitted arguments in others' speech. Future research can investigate how syntactic and discourse/pragmatic contexts may be integrated by children in learning about a new verb's argument structure.

The present study investigated whether Mandarin-speaking two-year-olds use the number of noun phrases in sentences to interpret a new verb. The present results provide the first evidence that young Mandarin learners, like their English-speaking counterparts, use sentence-structural cues in interpreting new verbs. Syntactic bootstrapping does appear to be an important part of verb learning for learners of languages other than English. The less reliable relation between the number of noun phrases in sentences and verb argument structure does not prevent young Mandarin learners from using noun-phrase number to interpret novel verbs. The finding that young learners of languages other than English engage in syntactic bootstrapping further suggests that children have access to certain unlearned syntax-semantics links—such as the relationship between the set of noun phrases in the sentence and the semantic predicate-argument structure of a verb—and are guided by them in early verb learning.

CHAPTER 4

"REALLY? SHE BLICKED THE BABY?"

TWO-YEAR-OLDS LEARN COMBINATORIAL FACTS ABOUT VERBS BY LISTENING[3]

Children use syntax as well as observations of events to learn verb meanings. This phenomenon is known as syntactic bootstrapping (Gleitman, 1990). Syntactic bootstrapping works because the syntactic structures licensed by each verb are systematically related to its meaning. For example, transitive verbs take two noun-phrase arguments (e.g., "He tickled him") and describe conceptual-semantic predicates involving two core participants (tickler, ticklee). In contrast, intransitive verbs take one noun-phrase argument ("He laughed") and describe conceptual-semantic predicates involving a single core participant (laugher).

In accord with these systematic relationships, children assign different interpretations to novel verbs appearing in different sentence structures (e.g., Fisher, 2002; Naigles, 1990). In one experiment, for example, 21-month-olds heard a made-up transitive ("He's gorping him!") or intransitive ("He's gorping!") verb while viewing two simultaneously presented events (Yuan, Fisher, Gertner, & Snedeker, 2007). One event involved two participants (one boy causing another to bend), and the other involved one participant (a boy making arm motions). Children hearing a transitive verb looked reliably longer at the two-participant event than did those hearing an intransitive verb.

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In the preceding example, the syntactic difference between the transitive and intransitive sentences could convey only aspects of verb meaning relevant to the number of participants involved—that is, relevant to the verb's semantic structure, but not to its semantic content (Grimshaw, 1993). Thus, the transitive structure ("He's gorping him!") informed children that the verb's meaning involved two participant roles; the verb's semantic content (e.g., "cause to bend") had to be gathered from observing the events (Fisher, 1996; Gleitman, 1990). But was observation of the events also necessary for children to identify the verb's semantic structure? In the experiments reported here, we investigated whether the syntactic structure in which a novel verb occurs independently conveys information about the verb's semantic structure to children, even when there is no concurrent referential scene providing clues to the verb's semantic content. Can children learn a new verb's combinatorial privileges—its transitivity and thus its number of participant roles—simply from listening to sentences in which the verb appears?

One possibility is that simultaneous access to syntactic and referential contexts is necessary for syntax to guide verb learning. Grimshaw (1994) proposed that children use syntax to guide verb interpretation by first generating a candidate interpretation of an observed scene, then generating an appropriate sentence to express that interpretation, and finally comparing this predicted sentence's structure with the input sentence; correspondence between the predicted and input sentences leads to learning about the verb's meaning. According to this proposal, the informativeness of syntax depends on scene-derived semantic content. Without a concurrent referential scene, no candidate interpretations are generated, and nothing is learned about the verb. This proposal is derived from lexical-projectionist accounts of the relationship between verb meaning and

syntax. According to these accounts, verbs' semantic representations determine their syntactic privileges (e.g., Levin & Rappaport Hovav, 2005); syntactic structure itself does not carry meaning independently of the verb.

An alternative possibility is that syntactic structures are independently meaningful, even without a concurrent scene providing information about a verb's semantic content. A child who hears the sentence "Jane blicked the baby!" in the absence of a helpful referential context could still learn that blick is transitive and therefore involves two participant roles. When the verb is later invoked in a referential setting, the child could retrieve this combinatorial information to guide the assignment of semantic content to the verb. This proposal depends on a key claim of the syntactic-bootstrapping theory (Gleitman, 1990) that is shared by constructional approaches to syntax and semantics (Goldberg, 1995): Syntactic structures themselves contribute meaning to sentences. According to this proposal, information about a new verb's syntactic context is informative independently of its semantic content.

Prior experimental studies of syntactic bootstrapping cannot be used to distinguish these alternatives, because all involved providing children with simultaneous access to syntactic and referential contexts (Fisher, 2002; Naigles, 1990; Yuan et al., 2007). In the experiments reported here, we separated these information sources, giving children syntactic and referential contexts for a novel verb that were separated in time and unrelated in content.

In two experiments, 2-year-olds were trained and tested on a novel verb. Figure 7 summarizes the procedure. First, in the dialogue phase, half the children encountered the verb in transitive sentences, and half encountered it in intransitive sentences. Later, in

event phases, the children viewed two simultaneously presented novel events: a two-participant event (one girl swinging another girl's leg) and a one-participant event (a girl making circles with her arm). During these event phases, the verb was presented in a syntactically uninformative context ("Find blicking!"). If children can learn combinatorial facts about a verb without knowing its semantic content, and can retrieve these facts when they hear the verb again, then children who heard transitive dialogues would be expected to interpret the verb as describing a two-participant relation and therefore to look longer at the two-participant event than children who heard intransitive dialogues.

Success in our task required that the children learn distributional facts about brand-new words, and there is considerable evidence that they can do this. Infants detect distributional patterns in word-segmentation and artificial-grammar-learning tasks (Gómez & Gerken, 1999; Marcus, Vijayan, Bandi Rao, & Vishton, 1999; Saffran, Aslin, & Newport, 1996), and they use distributional patterns to assign new words to major grammatical categories, such as noun and verb (Mintz, 2006). The present experiments extended the study of distributional learning about new words by moving to a new domain, syntactic subcategories within the verb category (transitive vs. intransitive), and by investigating whether this distributional learning affects the subsequent assignment of semantic content to a verb.

Success in our task also required that the children retrieve from their lexicon information about the verb's combinatorial privileges when they reencountered it. Again, there is evidence that young children can do this. Knowledge of the sentence-structure properties of particular verbs influences preschoolers' sentence comprehension (Gordon

& Chafetz, 1990; Snedeker & Trueswell, 2004) and production (Tomasello, 2000). As indicated by the two proposals we summarized earlier, however, learning a verb's sentence-structure properties could depend on knowledge of its semantic content (e.g., a verb meaning "tickle" requires two participants, and thus two noun-phrase arguments) or could be based in part on distributional learning. These two potential information sources are confounded in studies of familiar verbs. In the present research, we investigated whether children can learn combinatorial facts about a new verb from hearing sentences alone, and if they can later use these facts in interpreting sentences.

Most centrally, success in our task required that the children find sentence structures independently meaningful, without the aid of concurrent scenes.

Experiment 5

Method

Participants

Sixteen 2-year-olds (mean age = 28.6 months, range = 26.6–30.2 months; 8 girls, 8 boys) participated. All were native English speakers. An additional child was eliminated because of fussiness. The children's productive vocabularies, measured by the MacArthur-Bates Communicative Development Inventory (Level II, short form; Fenson et al., 2000), ranged from 29 to 100 (Mdn = 78.5).

Apparatus

Children sat on a parent's lap, facing two 20-in. television screens. The screens were separated by 12 in. and positioned 30 in. away from the children. Audio stimuli played from a central speaker. A hidden camera recorded children's eye movements.

Parents wore opaque glasses.

Materials and Procedure

The stimuli were videos of two women conversing and of people performing actions. The latter were accompanied by sound tracks recorded by a female native English speaker. All videos were combined into synchronized pairs for presentation on the two TV screens.

The procedure began with two practice trials involving familiar verbs, one intransitive (clap) and one transitive (tickle). Each trial involved three phases. In the dialogue phase of the first trial, two women uttered the verb clap in eight intransitive sentences (e.g., "Mary clapped!"). This dialogue consisted of two four-sentence video clips separated by a 3-s interval. Each video clip appeared on the two TV screens simultaneously. After a 7-s interval, Event Phase 1 began: Two 8-s video events played simultaneously, one on each screen, and children heard "Find clapping!" The target event showed a man clapping; the distractor event showed another man sleeping. Following a 3-s interval, this event pair was presented again in Event Phase 2.

After a 4-s interval, the second trial proceeded in the same manner. In the dialogue phase, children heard tickle in eight transitive sentences (e.g., "Hannah tickled Grandpa!"). In the event phases, the target event showed one woman tickling another; the distractor event showed one woman feeding another. The practice trials informed the children that one video in each event phase matched the sound track.

Following a 4-s interval, the children received a test trial in which a novel verb (blick) was introduced in the same manner (Fig. 7). In the dialogue phase, the novel verb was presented in eight transitive or eight intransitive sentences. In the event phases, the

children watched the two novel events and heard the verb in isolation (e.g., "Find blicking!").

The dialogue video clips averaged 27.0 s in duration (range = 24.1–29.7 s). The left/right position of the two test events was counterbalanced with dialogue condition.

Coding

From silent video, we coded where the children looked (left, right, or away from the test events) during the event phases, frame by frame. Reliability was assessed for 3 children; coders agreed on 98% of video frames.

Looking times to the two-participant event, to the one-participant event, and away from the events were averaged across the test-trial event phases.[4] Inspection of means suggested that children who heard intransitive dialogues tended to look away slightly longer (M = 0.54 s, SE = 0.24 s) than did children who heard transitive dialogues (M = 0.31 s, SE = 0.19 s). This difference was not reliable in Experiment 5 ($t < 1$), but the corresponding difference was reliable in Experiment 6. Given possible differences in look-away times, we conducted analyses on raw looking times to the two-participant event and to the one-participant event, rather than on a single measure of looking time to one event as a proportion of total looking time to the two events.

Preliminary analyses of test-trial performance revealed no interactions of dialogue condition with sex, or with whether children's vocabulary or practice-trial performance was above or below the median. The data were therefore collapsed across sex, vocabulary, and practice-trial performance.

[4] Data for an event phase were treated as missing if the child looked away for more than half of that event phase (two observations in Experiment 5 and three in Experiment 6).

Results and Discussion

As Table 3 shows, looking times during the test trial were affected by dialogue experience. Children who heard transitive dialogues looked reliably longer at the two-participant event than did those who heard intransitive dialogues, $\underline{t}(14) = 3.05$, $p_{rep} = .97$, $\underline{d} = 1.52$. They also looked less at the one-participant event than did those who heard intransitive dialogues, though this difference was not reliable, $\underline{t}(14) = 1.94$, $p_{rep} = .90$, $\underline{d} = 0.97$. Thus, 2-year-olds learned combinatorial facts about a novel verb in a nonreferential context, simply by listening. This knowledge subsequently influenced their attention to a two-participant event.

Experiment 6

In Experiment 5, 2-year-olds learned a new verb's combinatorial privileges from dialogues and later recruited that information in interpreting the verb. Thus, combinatorial information relevant to a verb's semantic structure can be acquired without access to the verb's semantic content. In Experiment 6, we sought to replicate this key result and addressed three additional questions.

First, could the children in Experiment 5 have detected a superficial pattern during the practice trials and used that pattern to guide their responses in the test trial? During the first practice trial, each sentence in the dialogue phase mentioned one participant, and each event in the event phases showed one participant. During the second practice trial, each dialogue sentence mentioned two participants, and each event showed two participants. This pattern might have led children who heard transitive sentences in the test-trial dialogue phase to prefer the two-participant event. To eliminate this

possibility, we omitted the dialogue phases for the practice trials; thus, in Experiment 6, the children had no opportunity to learn that the dialogues were related to the subsequent event phases.

Second, could the dialogue effect obtained in the test trial of Experiment 5 reflect sensitivity to the number of referents mentioned in the dialogue phase, rather than learning about the novel verb? Each sentence in the transitive dialogue mentioned two participants, whereas each sentence in the intransitive dialogue mentioned one. These sentences might have biased children in the transitive, but not the intransitive, condition to attend longer to the two-participant event in subsequent event phases. To eliminate this possibility, we added a control condition in which no novel verb was presented during the test-trial event phases. If the dialogue effect in Experiment 5 reflected learning about the novel verb, then it would disappear when no novel verb was presented during the test-trial event phases.

Third, we probed the robustness of children's learning by introducing a delay between the dialogue and event phases of the test trial. Two delay conditions were implemented. In both, the dialogue phase of the test trial was presented before the experiment proper began; then, the children received only the event phases of the practice and test trials. The event phases were presented immediately (same-day condition) or 1 to 2 days later (different-day condition).

Method

Eighty 2-year-olds (mean age = 28.4 months, range = 26.8–30.4 months; 44 girls, 36 boys) participated, 32 in the same-day and 48 in the different-day condition. Twelve additional children were eliminated because of side bias (n = 3), distraction (n = 1),

practice-trial performance (as measured by the average looking time to the target event in the practice trials) more than 2.5 standard deviations below the mean (n = 1), average looking time to the two-participant event in the test trial more than 2.5 standard deviations from the mean of the relevant condition (n = 3), or failure to return for the second session in the different-day condition (n = 4). Vocabulary scores ranged from 11 to 100 (Mdn = 72.5). Within each delay condition, children were assigned to one of the four combinations of dialogue (transitive, intransitive) and test (experimental, control) conditions.

The materials and procedure for the same-day condition were like those of Experiment 5, but with several changes. First, the dialogue phase of the test trial was presented before the experiment on an 8-in. portable DVD player. The experimenter then removed the DVD player and initiated the event phases of the practice and test trials, which again were presented on the two-screen display. The test-trial dialogue and event phases were therefore separated by a delay of 100 to 120 s. Second, the dialogue phase of the test trial included a third video clip with 4 additional sentences (12 total), to give the children ample opportunity to learn the verb's combinatorial privileges. Third, there were no dialogue phases for the practice trials. Fourth, in the test trial, children received three event phases rather than two, so they had ample opportunity to retrieve what they had learned about the new verb. Fifth, during the test-trial event phases, half the children in each dialogue condition heard the novel verb (experimental condition: "Find blicking!"), and half heard neutral utterances without the verb (control condition: "What's happening?").

The different-day condition was identical except that the dialogue phase of the

test trial was presented on a projection screen in another room and included a fourth video clip with 4 additional sentences (16 total). The event phases were presented either 1 day later (experimental condition: n = 16; control condition: n = 11) or 2 days later (experimental condition: n = 8, control condition: n = 13). Preliminary analyses of looking times in the different-day condition revealed no interactions of dialogue and test condition with whether testing occurred 1 or 2 days later (Fs < 1).

Coding reliability was assessed for 15 children and yielded 98% agreement. Preliminary analyses showed that look-away times varied with dialogue and test condition: A 2 (dialogue condition: transitive, intransitive) × 2 (test condition: experimental, control) × 2 (delay condition: same-day, different-day) analysis of variance revealed a marginal effect of dialogue condition, $F(1, 72) = 3.68$, $p_{rep} = .91$; an effect of test condition, $F(1, 72) = 4.64$, $p_{rep} = .93$; and an interaction of dialogue and test condition, $F(1, 72) = 4.33$, $p_{rep} = .93$. The means in Table 4 suggest that children in the intransitive-dialogue, experimental condition tended to look away longer than children in other conditions, at both delays. As noted earlier, the difference in look-away times led us to analyze raw looking times to the two- and one-participant events.

Preliminary analyses of test-trial performance revealed no interactions of dialogue and test condition with sex, or with whether children's vocabulary or practice-trial performance was above or below the median. The data were therefore collapsed across these factors.

Results and Discussion

Children who heard transitive dialogues looked longer at the two-participant event and less at the one-participant event than did those who heard intransitive dialogues, but

only in the experimental condition (see Table 4). The same pattern held at each delay.

Table 5 shows the results of 2 (dialogue condition: transitive, intransitive) × 2 (test condition: experimental, control) × 2 (delay condition: same-day, different-day) analyses of variance for the two looking-time measures. Analyses of looking times to the two-participant event revealed a significant effect of dialogue condition and a significant interaction of dialogue and test condition. As in Experiment 5, analyses of looking times to the one-participant event revealed similar, but less statistically robust, effects.

In the experimental condition, children who heard transitive dialogues looked reliably longer at the two-participant event than did those who heard intransitive dialogues, $\underline{t}(38) = 4.36$, $\underline{p}_{rep} = .99$, $\underline{d} = 1.38$. In the control condition, looking time to the two-participant event did not vary with dialogue condition ($\underline{t} < 1$). These effects held within each delay condition. That is, the effect of dialogue condition on looking time to the two-participant event emerged in the same-day, experimental condition, $\underline{t}(14) = 3.33$, $\underline{p}_{rep} = .98$, $\underline{d} = 1.66$, and in the different-day, experimental condition, $\underline{t}(22) = 2.95$, $\underline{p}_{rep} = .97$, $\underline{d} = 1.21$, but this effect did not emerge in the control condition at either delay ($\underline{t}$s < 1).

Similarly, in the experimental condition, children who heard transitive dialogues looked reliably less at the one-participant event than did those who heard intransitive dialogues, $\underline{t}(38) = 3.28$, $\underline{p}_{rep} = .99$, $\underline{d} = 1.04$. In the control condition, looking time to the one-participant event did not vary with dialogue condition ($\underline{t} < 1$). Separate comparisons within each delay condition revealed that the effect of dialogue condition was reliable in the different-day, experimental condition, $\underline{t}(22) = 2.53$, $\underline{p}_{rep} = .95$, $\underline{d} = 1.03$, but marginal in the same-day, experimental condition, $\underline{t}(14) = 2.08$, $\underline{p}_{rep} = .91$, $\underline{d} = 1.04$; dialogue

condition did not have a reliable effect in the control condition at either delay (ts < 1).

Why was the dialogue effect more robust in analyses of looking times to the two-participant event than in analyses of looking times to the one-participant event? The answer may be linked to our finding that in the experimental condition, children who heard intransitive dialogues looked away longer than did those who heard transitive dialogues. The means in Table 4 reveal a baseline preference for the two-participant event: Across conditions, children spent an average of 4.59 s (per 8-s event phase) looking at the two-participant event and 2.95 s looking at the one-participant event. They may simply have been unwilling to spend much more time looking at the one-participant event. Children in the intransitive-dialogue, experimental condition could also have looked away more than others because the intransitive verb was less constraining given the referential contexts provided at test. A transitive verb must refer to a two-participant event, but an intransitive verb could refer to a one-participant event or to part of a two-participant event (Naigles & Kako, 1993; Yuan et al., 2007).

Experiment 6 replicated and extended the findings of Experiment 5. Two-year-olds learned combinatorial facts about a novel verb in a nonreferential context and later retrieved these facts to interpret the verb. This dialogue effect appeared despite the absence of dialogue phases in the practice trials, which eliminates the possibility that the effect in Experiment 5 resulted from superficial patterns detected during the practice trials. The dialogue effect was restricted to the experimental group, which shows that the children linked what they learned during the dialogues to the novel verb; the presentation of the novel verb during the event phases cued the children to retrieve what they had learned. Experiment 6 yielded positive effects whether the dialogue and event phases

were separated by a delay of 2 min or by a delay of 1 to 2 days. Evidently, children's ability to learn combinatorial facts about a new verb from listening, and to retain those facts, is quite robust.

What was the source of the syntax-semantics links that permitted the children to draw semantic conclusions about the verb on the basis of its transitivity? In particular, could the children have learned during the experiment to link a transitive verb with a two-participant event? In the practice trials, children heard an intransitive ("Find clapping!") and a transitive ("Find tickling!") verb accompanied by appropriate events. Because the children knew these verbs and their transitivity, these trials could have provided training in the link between verb transitivity and number of event participants. This account of our results still requires that the children learned the new verb's combinatorial properties from the dialogues. However, according to this explanation, children's ability to use that knowledge to interpret the verb was supported by learning during the experiment. Prior evidence renders it unlikely that the children's success depended entirely on learning during the experiment: Two-year-olds appropriately interpret simple transitive and intransitive sentences containing novel verbs in tasks with no practice trials (Fisher, 2002; Gertner, 2007; Naigles, 1990). Such findings suggest that children at this age already possess some knowledge of the relevant syntax-semantics links. Nevertheless, it remains possible that in our restricted testing context, the practice trials might have indirectly supported comprehension of the novel verb, perhaps by priming useful syntactic-semantic representations (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008). Future experiments will explore this possibility.

General discussion

In two experiments, 2-year-olds learned about a new verb's combinatorial privileges from brief dialogues, without a referential context that hinted at the verb's semantic content. If they later encountered the verb in a referential context, they retrieved this combinatorial information and used it to guide their attention to candidate events. Children who had heard the verb used transitively looked longer at a two-participant event than did those who had heard the verb used intransitively. This effect persisted when testing occurred on a different day. These experiments provide compelling new evidence for a key assumption of syntactic bootstrapping—that sentence structures carry meaning independently of the verbs in those structures. These findings also raise interesting questions for future research about the nature of the combinatorial information children acquired about the new verb from their listening experience.

First, how did the children encode the dialogue sentences? During the dialogues, the children could have created lexical entries with the linguistic status of new transitive or intransitive verbs. Alternatively, they could have created shallower representations, noting that the new verb occurred with two nouns, or with one. Under some circumstances, 25-month-olds distinguish transitive sentences ("The duck is gorping the bunny!") from two-noun intransitive sentences ("The duck and the bunny are gorping!"; Naigles, 1990). In our dialogues, however, the challenge of encountering sentences without referential support might have caused the children to resort to shallower representations. Crucially, even shallow sentence representations should lead to success in this task. Elsewhere we have proposed that children are biased to interpret each noun in a sentence as a semantic argument of a predicate term (Fisher, 1996). According to this

proposal, as soon as children can identify some nouns, they assign different interpretations to transitive and intransitive verbs by mapping a two-noun verb onto a two-participant conceptual predicate and a one-noun verb onto a one-participant conceptual predicate. This proposal suggests that even children younger than 2 years old might succeed in a version of this task. Future experiments will pursue this possibility, and explore 2-year-olds' sentence representations by presenting dialogues that disentangle transitivity from the number of nouns.

Still another possibility is that the children remembered one or more dialogue sentences verbatim, rather than encoding a more abstract representation. This would be akin to an instance-based account of our findings. Note that even such an instance-based account would involve interesting generalization on the child's part: Retrieved instances of sentences such as "Jane blicked the baby" or "Jim is gonna blick the cat" did not prevent the children from extending the new verb to a two-participant event involving two grown women. This suggests that useful abstraction of some form took place, whether upon retrieval (in an instance-based system) or upon encoding (in an abstractionist system).

Second, did the children engage in semantic processing while encoding the dialogue sentences? Even without a useful referential context, the children might have used the distributional information available in the dialogue sentences (e.g., two-noun or transitive verb) to infer an appropriate semantic structure (two participant roles). Alternatively, the children could have gathered the distributional information without inferring a semantic structure until they encountered the verb in a referential context. We anticipate that the dialogue-and-test method introduced here will allow us to address this

issue, by manipulating the content of the dialogue sentences and the referential options provided at test. For example, in a recent extension of this task, 2-year-olds' interpretations of a verb reflected the characteristics of the nouns that filled the verb's argument slots during the dialogues (e.g., the nouns' animacy; Scott & Fisher, in press). This finding suggests that the children assigned a partial interpretation to the sentences containing the novel verbs while they listened to the dialogues, in the absence of a referential scene.

The ability to gather combinatorial facts about unknown verbs by listening, and to retain these facts over time, could help solve a problem for syntactic bootstrapping and for syntax acquisition: Sentences can contain extra (adjunct) phrases, and in many languages, verbs' arguments can be omitted if they are recoverable in the discourse context. Thus, individual sentences are not reliable indicators of a verb's argument structure. In principle, learners could overcome this difficulty by gathering syntactic information across many sentences to estimate each verb's argument structure (Fisher & Gleitman, 2002). The present findings suggest that children have the necessary tools to do this. Two-year-olds interpret a sentence using not only the syntactic information available in the current sentence, but also the verb's syntactic history.

CHAPTER 5

CONCLUSIONS

Children between two and five years of age assign different interpretations to novel verbs in different sentence structures, providing support for the syntactic bootstrapping theory. The studies reported in this dissertation were motivated by three central questions about the origins and mechanisms of syntactic bootstrapping. The first question centered on how syntactic bootstrapping might begin: What kind of knowledge about the links between verb syntax and meaning do young children need in order to begin structure-guided learning, and where does this knowledge come from? The second question concerned the universality of syntactic bootstrapping: Is syntactic bootstrapping a fundamental part of verb learning for learners of different languages, despite relevant syntactic differences among languages? The final question targeted the mechanisms underlying syntactic bootstrapping: Is sentence-structural information informative independent of information from observed events?

Origins of syntax-semantics links

Prior research provided no indication that children younger than two years use aspects of sentence structure to interpret novel verbs (e.g., see Naigles and Swensen, 2007). In contrast, in Chapter 2, I reported new evidence that children at 21 and even 19 months of age show sensitivity to the sentence structure in interpreting novel transitive and intransitive verbs, as long as the number of nouns in the sentence is informative. Moreover, their use of the number of nouns in novel-verb interpretation is guided by their

conceptual representations of relations and core participants in events, resulting in the alignment between nouns in the sentence and core participants in an event. This is the first evidence that children younger than two years use aspects of sentence structure to appropriately interpret novel transitive and intransitive verbs. The findings together confirm the predictions of the structure-mapping account: that structure-guided learning takes place early and that children's use of sentence-structural information is constrained by their structured conceptual representations of events. This suggests that syntactic bootstrapping originates in an intrinsic bias to assign each noun in the sentence to a core participant-role in a conceptual representation. Because young children both represent the set of nouns in a sentence and consider core event participants as candidate referents for each of those nouns, simple aspects of the sentence structure can be meaningful to children from the start of multi-word sentence comprehension.

Our findings add to the existing evidence for syntactic bootstrapping and help extend our knowledge of its developmental course. While older children have been shown to use relatively complex sentence-structural cues (e.g., true syntactic transitivity, sentence complements; Naigles, 1990; Papafragou et al., 2007), the present experiments showed that younger children, even before they have learned many of the language-specific details of the syntax, can get started by using simpler aspects of sentence structure: namely, the set of nouns in the sentence. The ability to create and use such simple representations of sentences, as proposed by the structure-mapping account, leads to other consequences. For example, children can use the number of nouns to learn not only new verbs but to learn the argument-taking properties of predicate terms in general (e.g., learning of prepositions, Fisher et al., 2006). Moreover, without sophisticated

language-specific syntactic knowledge, these simple sentence representations can lead young children to make predicted errors in comprehension (e.g., Connor, et al., 2008; Gertner & Fisher, 2009).

Could our finding of early sensitivity to sentence-structural information be explained by the construction-based learning account? In principle, it could be that by 19 months of age, children have already acquired generalizations about the relationship between the number of nouns in sentences and the number of participant-roles, based on whatever degree of verb-by-verb learning they have achieved by this age. Given that 19-month-olds have small vocabularies in which verbs represent a small percentage (e.g., Caselli et al., 1999), we consider it unlikely that this one-to-one correspondence relation between nouns in sentences and participant-roles is abstracted from the knowledge of the few verbs they know. Testing even younger infants could be informative. The structure-mapping account predicts that children should be able to use the number of nouns as a cue in verb interpretation as soon as they can identify a few nouns in sentences and represent them as parts of a larger utterance. In other words, once children begin to show signs of comprehension of multi-word sentences—around 14 to 16 months (Hirsh-Pasek & Golinkoff, 1996; Seidl et al., 2003; Lidz & Baier, 2008)—they should be able to make use of the number of nouns in sentences. Future research will extend the investigation to younger infants. The younger the infants yielding some positive evidence, the less likely the one-to-one correspondence relation results from item-based learning, and the more likely it originates from an unlearned bias.

Our findings of early syntactic bootstrapping with 19- and 21-month-olds join evidence from others in suggesting that young children are capable of representing their

linguistic experience in abstract terms. For example, studies of syntactic priming in young children demonstrate that 3-year-olds' production and comprehension of sentences are influenced by whether the sentences share abstract structural similarity with previously experienced sentences (Bencini & Valian, 2008; Shimpi, Gámez, Huttenlocher & Vasilyeva, 2007; Thothathiri & Snedeker, 2008). Furthermore, studies of comprehension of novel verbs in transitive sentences suggest that 21-month-olds interpret transitive sentences with abstract notions such as 'proto-agent' and 'proto-patient' (Gertner et al., 2006). Our findings join these prior findings in demonstrating that young children are capable of forming representations of sentences that are not tied to particular verbs and nouns, thus allowing early generalization and learning of new verbs.

It has been suggested, however, that positive findings from comprehension studies such as ours might be considered evidence of 'weak' representations of abstract sentence structure in young children (Tomasello & Abbott-Smith, 2002). What does it mean to have 'weak' representations of abstract sentence structure? It may well be that representations of syntactic knowledge that could drive comprehension but not production are in some sense weaker because success in comprehension tasks may be achieved with partial abstract representations of sentences (Chang, Dell & Bock, 2006). To successfully produce a transitive sentence, for example, a child has to get the subject, the verb, and the object all in their correct positions, in the correct word retrieved for each. To successfully comprehend one, at least in a forced-choice task such as our preferential-looking task, children might get along with multiple different partial representations of the sentence (e.g., a sentence with a set of two nouns, a verb followed by a noun). While young children's abstract representations of sentence structure as

witnessed in our tasks have not been demonstrated in production tasks, they are strong enough to drive comprehension and word learning, suggesting they do play a functional role in language development.

Moreover, the results reported in Chapter 2 show that young children's use of abstract structural representations in the interpretation of a new verb is robust. It does not require learning or priming via relevant linguistic experience within the task, contrary to what some have argued (Dittmar et al., 2008). That is, the 19-month-olds succeeded in assigning appropriately different interpretations to novel transitive and intransitive verbs even without familiar-verb practice trials that set up a contrast between a transitive and an intransitive verb along with the matching two- and one-participant events. This suggests that the kind of abstract structural knowledge young children demonstrate in our tasks is in place prior to their participation in the study.

Universality of syntactic bootstrapping

How universal is syntactic bootstrapping? Chapter 3 investigated whether Mandarin-speaking two-year-olds, like their English-speaking counterparts, make use of sentence-structural cues in interpreting novel verbs. Frequent argument omission in Mandarin makes the number of noun phrases a noisier cue to the verb's semantic predicate-argument structure. The less reliable relationship might make it more difficult for children to learn, for example, that two-noun sentences convey two-participant relationships, while one-noun sentences do not. In Chapter 3, I reported evidence that 2-year-old Mandarin learners nevertheless use the number of noun phrases in verb interpretation, just as English-speaking children do. This is consistent with the possibility

that children did not have to learn the semantic consequences of the number of noun phrases, providing additional support for the assumption of the structure-mapping account that young learners are guided by a one-to-one mapping bias between noun phrases in sentences and semantic participant roles. This finding adds to the prior findings of syntactic bootstrapping in languages beyond English (Lee & Naigles, 2008; Göksun et al., 2008; Lidz et al., 2003; Cheung, 1998) and extends them by testing young Mandarin learners on novel-verb interpretation. Joining the prior work, the finding in Chapter 3 suggests that syntactic bootstrapping is a fundamental part of verb learning for non-English learners as well, even in languages that provide much less evidence for a reliable link between noun-phrase number and verb argument-structure in the input.

The demonstration that Mandarin learners use sentence-structural cues in verb learning is, however, orthogonal to questions about the sentence-by-sentence informativeness of sentence-structural cues for verb-learning in the language. Given that nouns could be dropped from sentences in Mandarin, there is a less reliable relation between the number of noun phrases and the number of verbs' arguments in Mandarin. Even though Mandarin learners do show sensitivity to the number of noun phrases in interpreting novel verbs, one might wonder whether the use of number of noun phrases would be less useful for learning verbs in Mandarin than in English. To illustrate, if a Mandarin-speaking child did not know the meaning of 'take' and encountered it in (1), she might then be misled by the single noun phrase in the sentence to incorrectly conclude that 'take' refers to an event involving one core participant, rendering the use of noun-phrase number not useful.

(1) Q: Neiben shu ne?

that book QUESTION-particle

What happened to that book?

A: Ta nazou le.

he take-away PAST-particle

He took (it) away.

One way the noun-phrase number might still be useful in Mandarin is that learners arrive at the noun-phrase number not just via the surface evidence from the individual sentence containing the verb but also by attending to discourse and pragmatic cues. Analyses of children's speech in some languages permitting argument omission indicate that young children are sensitive to discourse and pragmatic cues in their own language production (Rispoli, 1992; Lan, 1999; Allen, 2000; Clancy, 2003; Narasimhan et al., 2005). For example, children are more likely omit a noun phrase in their own sentences once the referent has been established as the topic in the discourse or when the referent is already the target of joint attention between the speaker (the child) and listener (Skarabela & Allen, 2002). Omitting an argument in one's own speech due to high discourse prominence, however, is different from establishing a missing argument in someone else's sentence. Little is known about young children's sensitivity to pragmatic information in language comprehension. However, if children also consider entities that have been prominently established as topics in the discourse context when interpreting potential omitted arguments in others' speech, then they could 'recover' the missing noun-phrase argument and still arrive at an accurate number of noun-phrase arguments for verbs. For example, in addition to the lone overt noun phrase in (1) ("he"), children may infer that the verb 'take' licenses a second noun-phrase ("that book") whose referent

has been previously established in the discourse. Some recent findings indicate that 2- to 4-year-old English learners make use of pragmatic information to interpret and "fill in" the missing noun phrases of input sentences containing familiar verbs (e.g., "*The zebra brings"), suggesting a possible role for pragmatic information in helping to form syntactic representations (Naigles & Maltempo, 2007).

Distributional learning offers a promising route for noun-phrase number to still be useful to Mandarin learners: Children may arrive at an estimate of the noun-phrase number from gathering data across many utterances containing the same verb (Fisher & Gleitman, 2002). In Mandarin, while the number of noun-phrases in an individual sentence is a less reliable indicator of the verb's underlying argument-structure than it is in English, there is still probabilistic information about verbs' argument structures across collections of utterances (Lee & Naigles, 2005): Overall, transitive verbs are still more likely to be followed by a post-verbal noun-phrase in Mandarin casual speech than intransitive verbs are (40% vs. 17%). In principle, children could derive the intended argument structure of a verb by keeping track of the overall probabilistic pattern of occurrences of noun-phrases with the verb across utterances. Thus, to interpret the verb 'take' in (1), a Mandarin learner could use the number of noun-phrases previously derived from multiple utterances, rather than just the number of noun-phrases in that individual sentence. Crucially, while the learner may have to 'discover' from the voluminous input the number of noun phrases a particular verb occurs with, our findings suggest that she would not need to learn the semantic consequences of it.

For the aggregate number of noun-phrase to be useful, children need to be able to gather information about the argument-taking behaviors of a verb over sentences and use

it to interpret the verb in a less informative structure. The finding from Chapter 4 that children can learn and retain the combinatorial properties of verbs from mere sentence exposure suggests that children have the necessary tools to do so, by using the verb's syntactic history to interpret an individual sentence. Learning about the combinatorial properties of verbs from wealth of sentences children encounter may be a robust and early part of establishing a meaningful verb lexicon. This wealth of data might make the use of simple syntactic cues as important a part of verb learning in argument-dropping languages like Mandarin as in English.

Independent encoding of sentence-structural information

The final portion of this dissertation focused on the question on the mechanisms of syntactic bootstrapping: How is sentence-structural information used in relation to information from observed events? In all the prior experimental studies of syntactic bootstrapping, children were provided with simultaneous access to both sentence-structural and event information. The event information is certainly useful in many ways. While the sentence-structural information leads the learner to focus on particular aspects of the observed events by providing information relevant to the verb's semantic structure (e.g., a two-participant relation), the events enrich the verb's meaning by providing details for its semantic content (e.g., specifying the relation as one person bending another, not tickling him). Furthermore, given the same sentence-structural information, some kinds of events promote certain kinds of interpretations more than other kinds of events do. For example, situations involving a salient mental state (e.g., a false belief held by an event participant) would invite children to generate more mentalistic interpretations

to a novel verb occurring in with a sentence complement ("Matt gorps that his grandmother is under the covers!") than would situations without a salient mental state (Papafragou et al., 2007). Without referential information from concurrent events, can children learn useful information about a new verb from sentence-structural information alone?

In Chapter 4, I reported the finding that 2-year-olds can learn about a new verb's combinatorial privileges—its transitivity and participant-role number—from brief dialogues, without a referential context that hinted at the verb's semantic content. They can later retrieve this combinatorial information and use it to guide their interpretation when it is presented in a referential context. This finding provides compelling new evidence for a key assumption of syntactic bootstrapping—that sentence structures carry meaning independently of the verbs in those structures. The dialogue-and-test method used in this study to separate the sentence-structural and event information sources provides a new approach to explore what information children encode from sentence-structural information (Scott & Fisher, 2009; Choi et al., 2009).

While our findings indicate that the children encoded useful combinatorial information about a verb from sentences in the dialogues, it is unclear to what extent they engaged in semantic processing during the dialogues. Upon encountering sentences in the dialogues such as "Jane blicked the baby," children could have gathered only syntactic facts (e.g., two-noun or transitive verb) without making any semantic conjectures until they encountered the verb in a referential context. Alternatively, in addition to encoding the syntactic facts during the dialogues, children could have inferred an appropriate semantic structure (two participant roles) or, more specifically, even represented some

conceptual relation between the referents of the specific mentioned nouns (e.g., some event involving a woman named Jane and a baby as core participants). It seems clear that adults have the experience of speculating what sentences containing unknown words might refer to. Wykes and Johnson-Laird (1977) showed that 4-year-olds are capable of doing so: After children heard stories containing a new verb along with salient information about what categories of objects could serve as the subject of the new verb (e.g., "The water mibbed his trousers so he went home to change into some dry clothes."), they could pick out a new member of the category as a potential agent involved in the verb meaning (e.g., picking a new liquid as something that could 'mib'). Younger children have been shown to be able to create semantic interpretations of sentences without referential support from a concurrent scene. Near the beginning of second year of life, infants show comprehension of references to objects that are not in view, at least under some circumstances (Ganea, 2005; Saylor, 2004). Furthermore, by 22 months, children show evidence that they can update their mental representations of absent objects upon hearing narratives about them (Ganea, Shutts, Spelke, & DeLoache, 2007). These findings suggest that, as young children listen to sentences without concurrent contextual support from a scene, they are capable of setting up a situation model to include the referents and to predicate things about them. Thus, we consider it likely that the 28-month-olds in our task did not stop at encoding the syntactic facts during the dialogues but further assigned partial interpretation to the sentences containing the novel verb.

The possibility that children may engage in some level of semantic encoding of sentences containing a novel verb without a corroborating scene has implications for the

structure-mapping account. It suggests that the conceptual representations in the structure-mapping procedure need not be constructed from a concurrently observed scene to which the sentence is assumed to refer. Instead, children may be able to generate a conceptual representation to align with the sentence representation even without contextual support from a scene. Importantly, while a conceptual representation constructed from hearing the sentence alone (e.g., some relation [a woman named Jane, a baby]) would undoubtedly have fewer details than a conceptual representation constructed from a concurrently observed scene (e.g., feed [woman, baby]), these two kinds of conceptual representations could be mapped onto the sentence representation in just the same way, via the assumed one-to-one correspondence relation between nouns in sentences and participant-roles in conceptual/semantic representations.

In summary, this dissertation explored the origins and mechanisms of syntactic bootstrapping. Young learners expect structural parallels between language and conceptual representations of events. In particular, they assume a one-to-one mapping between nouns in sentences and participant-roles. This simple bias serves as a precursor of the complete set of syntax-semantics links that participate in mature sentence processing, allowing young learners to engage in structure-guided learning in the earliest stages of language development and to do so even in languages in which the relations between surface syntax and underlying verb semantics are less transparent. Because learners find sentence-structural information independently meaningful, they are equipped to learn aspects of verb meaning without contextual support from a scene. Taken together, the kinds of sentence and conceptual representations children have, along with their ability to integrate them, lead to finding meaning in syntax from the start.

Table 1: Mean proportion (se) of looking-time to the two-participant event out of the total time spent looking at either test event, averaged across the two (Experiments 1-3) or three trials (Experiment 3 additional results) of the test item.

	Paired test event	Transitive condition	Intransitive condition	Neutral condition
Experiment 1 (21-month-olds)	One-participant event	.67 (.05)	.45 (.08)	.52 (.04)
Experiment 1 – Additional Results (21-month-olds)	One-participant event	.70 (.06)	.49 (.04)	--
Experiment 2 (21-month-olds)	Bystander event	.66 (.06)	.46 (.05)	.44 (.06)
Experiment 3 (19-month-olds)	One-participant event	.67 (.02)	.53 (.06)	.50 (.05)
Experiment 3 – Additional Results (19-month-olds)	Bystander event	.53 (.05)	.36 (.02)	--

Note. Standard errors are given in parentheses.

Table 2: Mean (se) proportion of looking time to the two-participant event, averaged across the three trials during the novel-verb test phase, Experiment 4.

	Transitive condition	Intransitive condition	Neutral condition
With-listening-phase	.66 (.02)	.55 (.04)	.58 (.02)
No-listening-phase	.68 (.04)	.52 (.06)	.54 (.06)
Overall	.67 (.02)	.54 (.04)	.56 (.03)

Note. Standard errors are given in parentheses.

Table 3

Mean Looking and Look-Away Times (in Seconds), Averaged Across the Two Event Phases, in the Test Trial in Experiment 5.

	Looking time		
Dialogue type	Two-participant event	One-participant event	Look-away time
Transitive	4.82 (0.43)	2.87 (0.51)	0.31 (0.19)
Intransitive	3.33 (0.24)	4.12 (0.40)	0.54 (0.24)

Note. Standard errors are given in parentheses.

Table 4

Mean Looking and Look-Away Times (in Seconds), Averaged Across the Three Event Phases, in the Test Trial in Experiment 6.

Dialogue type	Same-day condition		Different-day condition		Overall	
	Experi-mental	Control	Experi-mental	Control	Experi-mental	Control
Looking time to the two-participant event						
Transitive	5.41 (0.38)	4.30 (0.41)	5.02 (0.27)	4.82 (0.30)	5.17 (0.22)	4.61 (0.24)
Intransitive	4.11 (0.09)	4.60 (0.45)	3.90 (0.26)	4.57 (0.32)	3.99 (0.16)	4.58 (0.26)
Looking time to the one-participant event						
Transitive	2.28 (0.33)	3.32 (0.44)	2.52 (0.24)	2.80 (0.30)	2.43 (0.19)	3.01 (0.25)
Intransitive	3.09 (0.19)	3.10 (0.45)	3.50 (0.30)	3.00 (0.31)	3.33 (0.20)	3.04 (0.25)
Look-away time						
Transitive	0.30 (0.07)	0.37 (0.12)	0.46 (0.10)	0.38 (0.10)	0.40 (0.07)	0.38 (0.08)
Intransitive	0.80 (0.16)	0.30 (0.05)	0.60 (0.14)	0.43 (0.10)	0.68 (0.10)	0.38 (0.06)

Note. Standard errors are given in parentheses.

Table 5

Analysis of Variance Results for Looking Times in Experiment 6.

Effect	Two-participant event	One-participant event
Dialogue condition	$F(1, 72) = 6.56$*	$F(1, 72) = 3.55$†
Test condition	$F(1, 72) < 1$	$F(1, 72) < 1$
Delay condition	$F(1, 72) < 1$	$F(1, 72) < 1$
Dialogue Condition × Test Condition	$F(1, 72) = 7.14$**	$F(1, 72) = 3.74$†
Dialogue Condition × Delay Condition	$F(1, 72) < 1$	$F(1, 72) < 1$
Test Condition × Delay Condition	$F(1, 72) = 1.40$	$F(1, 72) = 1.87$
Dialogue Condition × Test Condition × Delay Condition	$F(1, 72) < 1$	$F(1, 72) < 1$

†$p < .1$, $p_{rep} = .91$. *$p < .05$, $p_{rep} = .96$. **$p < .01$, $p_{rep} = .97$.

Figure 1. Schematic diagram of an example of structure mapping.

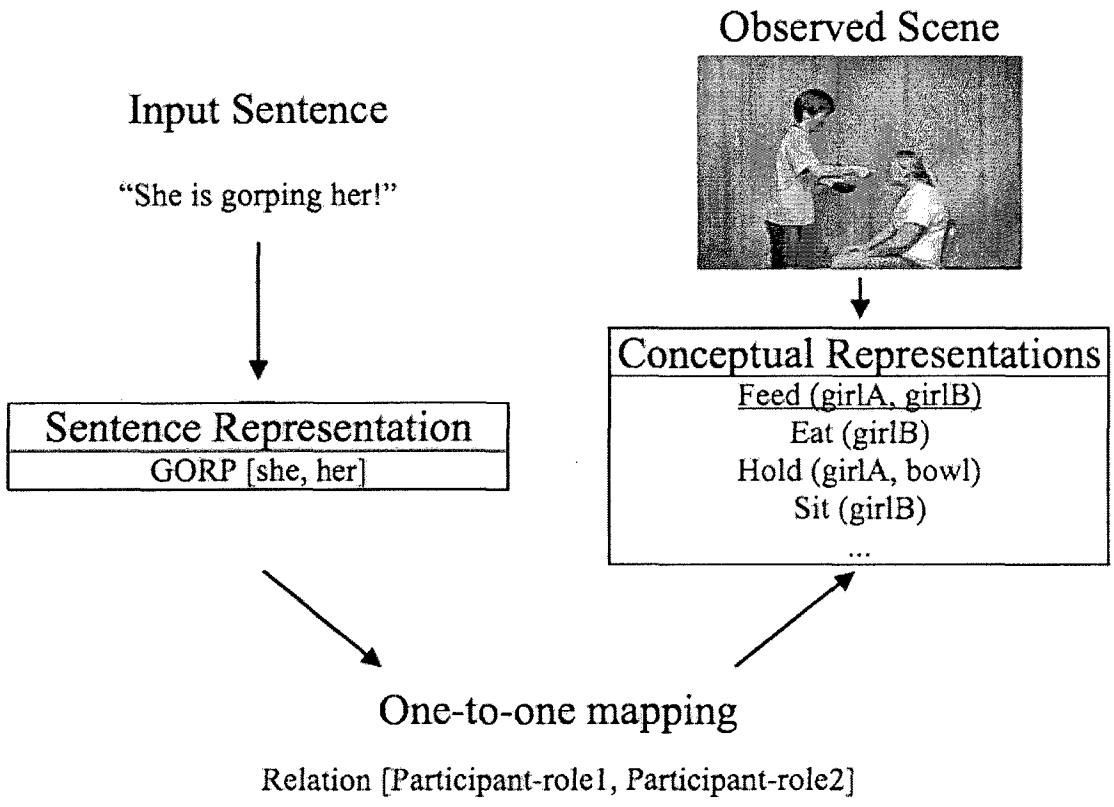
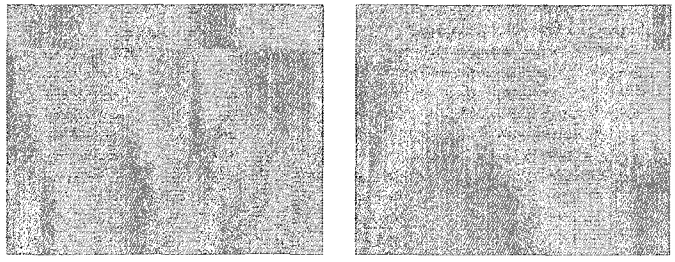
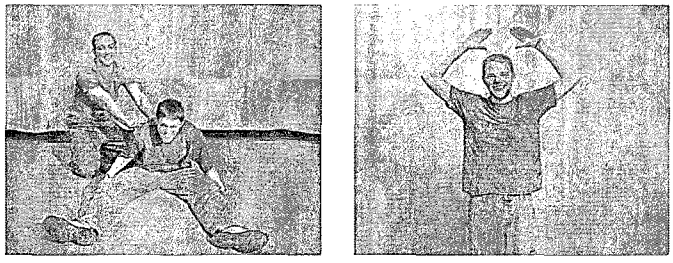


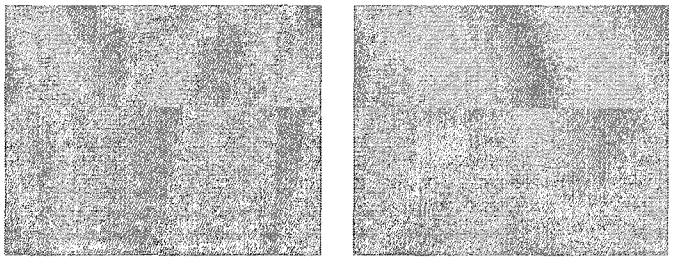
Figure 2. Sequence of events in the novel-verb item of Experiment 1 (21-month-olds).



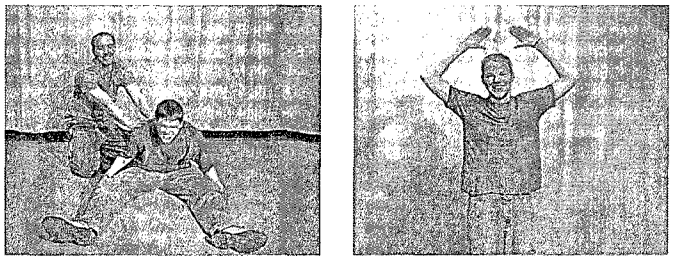
Blank-screen interval (4s):
Watch!
He's gonna gorp (him)!



First test trial (8s):
He's gorping (him).
He's gorping (him).
See?
He's gorping (him).



Blank-screen interval (3s):
Find gorping.



Second test trial (8s):
He's gorping (him).
Find gorping.
Find gorping.

Figure 3. Pair of novel events for the novel-verb item, replication of Experiment 1 (21-month-olds).

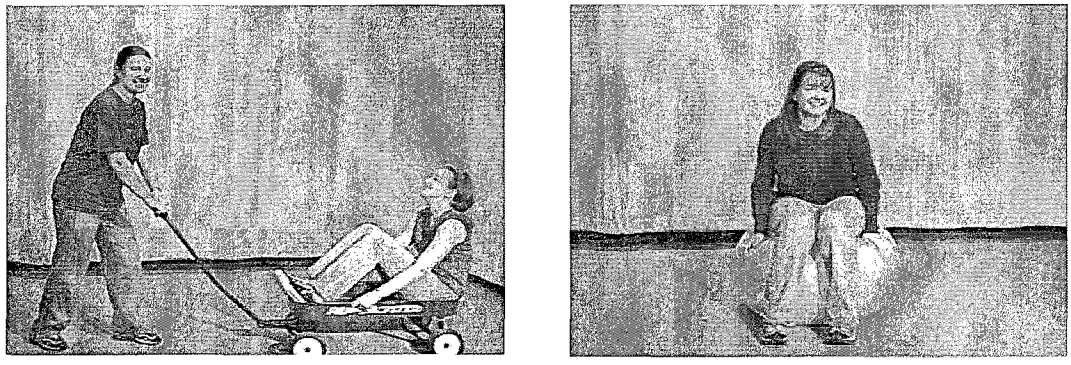
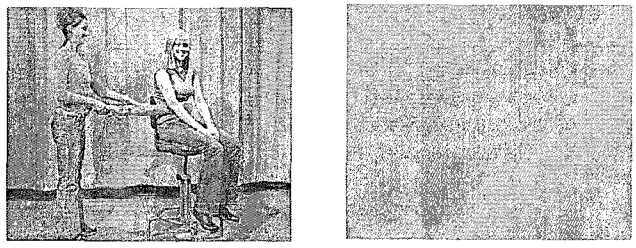
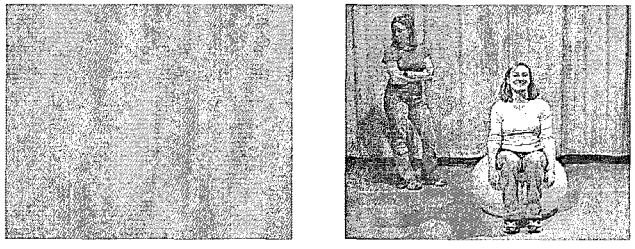


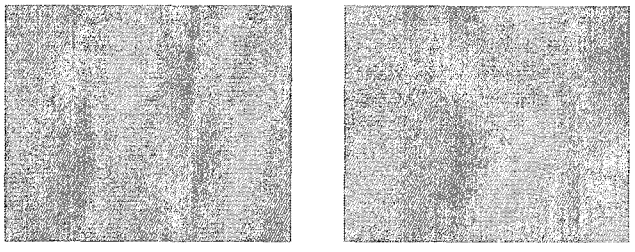
Figure 4. Sequence of events in the novel-verb item of Experiment 2 (21-month-olds).



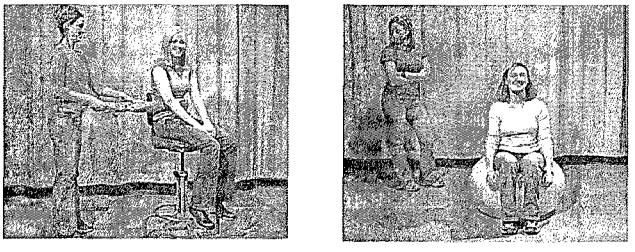
Preview (5s):
Hey watch!
Look here. See this?



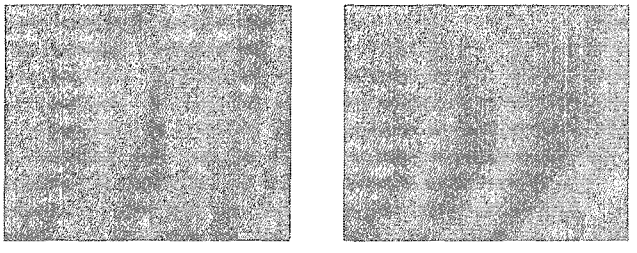
Preview (5s):
Ooh look!
Look over here. Watch this!



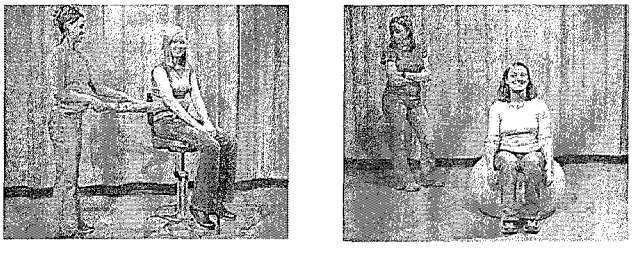
Blank-screen inveral (6s):
Now watch!
She's gonna flom (her)!
She's gonna flom (her)!



1st test trial (8s):
She's flomming (her).
She's flomming (her).
See? She's flomming (her).



Blank-screen inveral (6s):
She flommed (her).
Find flomming.

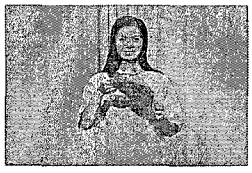


2nd test trial (8s):
She's flomming (her).
Find flomming.
Find flomming.

Figure 5. Sequence of events in Experiment 3 (19-month-olds).

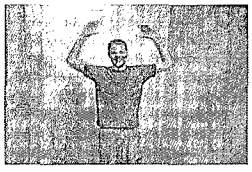

MONOLOGUE PHASE

Transitive Dialogue	Intransitive Dialogue
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.
----	----
Guess what?	Guess what?
Emma gorped the baby.	Emma gorped.
Yeah, she gorped the baby.	Yeah, she gorped.
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 6. Listening phase (only for the With-listening-phase condition) and test phase (for all the children) for the novel verb, Experiment 4.

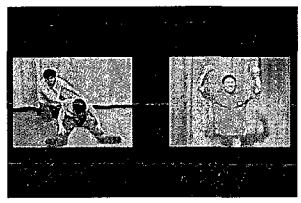
LISTENING PHASE

Transitive & Control (half)
A: Hey, Hong-Hong yao FO xiao-go-go le.
(*Hey, Hong-Hong is gonna FO puppy.*)

B: Wow. Tao yao FO xiao-go-go?
(*Wow. He's gonna FO puppy?*)
...

Intransitive & Control (half)
A: Hey, Hong-Hong yao FO le.
(*Hey, Hong-Hong is gonna FO.*)

B: Wow. Tao yao FO?
(*Wow. He's gonna FO?*)
...



TEST PHASE

Transitive — Ta zai FO ta. Ta zai FO ta... Na bian zai FO?
(*He's FOing him. He's FOing him... Which side is FOing?*)

Intransitive — Ta zai FO. Ta zai FO... Na bian zai FO?
(*He's FOing. He's FOing... Which side is FOing?*)

Control — Ni kan dao le she me? Zai zuo she me? Kan dao mei you?
(*What do you see? What's happening? See?*)

Figure 7. Dialogue and event phases for the novel verb in Experiment 5. Half the children heard transitive dialogues, and half heard intransitive dialogues. The transitive and intransitive dialogues were identical except for the presence versus absence of the direct-object noun phrase in each sentence. In the event phases, all children watched the same two novel events and heard the verb in syntactically uninformative sentences.

DIALOGUE PHASE

Screen 1	Screen 2	*Transitive dialogues*:	*Intransitive dialogues*:
		A: Hey...Jim is gonna blick the cat! B: Really? He's gonna blick the cat? A: And Mary was blicking the man. B: Wow, she was blicking the man. — A: Guess what? Jane blicked the baby! B: Hmm, she blicked the baby? A: And Bill was blicking the duck. B: Yeah, he was blicking the duck.	A: Hey...Jim is gonna blick! B: Really? He's gonna blick? A: And Mary was blicking. B: Wow, she was blicking. — A: Guess what? Jane blicked! B: Hmm, she blicked? A: And Bill was blicking. B: Yeah, he was blicking.

EVENT-PHASE 1

Screen 1	Screen 2	
		"Find blicking! Where's blicking? See? Where's blicking?"

EVENT-PHASE 2

Screen 1	Screen 2	
		"Find blicking! Where's blicking? Find blicking! Find blicking!"

REFERENCES

Akhtar, N. (1999). Acquiring basic word order: Evidence for data-driven learning of syntactic structure. Journal of Child Language, 26, 339-356.

Akhtar, N., & Tomasello, M. (1997). Young children's productivity with word order and verb morphology. Developmental Psychology, 33, 952-965.

Allen, S. (2000). A discourse-pragmatic explanation for argument representation in child Inuktitut. Linguistics, 38, 483-521.

Baillargeon, R. (2004). Infants' physical world. Current Directions in Psychological Science, 13, 89-94.

Bavin, E.L., & Growcott, C. (2000). Infants of 24-30 months understand verb frames. In Perkins and S. Howard (Eds.), New directions in language development and disorders (pp. 169-177). New York: Kluwer.

Bencini, G.M.L., & Valian, V. (2008). Abstract sentence representation in 3-year-olds: Evidence from comprehension and production. Journal of Memory and Language, 59, 97-113.

Bloom, L. (1970). Language development: Form and function in emerging grammars. Cambridge, MA: MIT Press.

Booth, A.E., & Waxman, S.R. (2009). A horse of a different color: Specifying with precision infants' mappings of novel nouns and adjectives. Child Development, 80, 15-22.

Bowerman, M., & Brown, P. (2007). Crosslinguistic perspectives on argument structure: Implications for learnability. Hillsdale, NJ: Erlbaum.

Brandone, A., Addy, D.A., Pulverman, R., Golinkoff, R.M., & Hirsh-Pasek, K. (2006). One-to-one and two-for-two: Anticipating parallel structures between events and language. In D. Bamman, T. Magnitskaia, & C. Zaller (Eds.), Proceedings of the 30th Annual Boston University Conference on Language Development (pp. 36-47). Somerville, MA: Cascadilla Press.

Brent, M.R. (1994). Acquisition of subcategorization frames using aggregated evidence from local syntactic cues. Lingua, 92, 433-470.

Brooks, P.J., & Tomasello, M. (1999). Young children leanr to produce passives with nonce verbs. Developmental Psychology, 35, 29-44.

Caselli, C., Casadio, P., & Bates, E. (1999). A comparison of the transition from first words to grammar in English and Italian. Journal of Child Language, 26, 69-111.

Carey, S. (1978). The child as word learner. In J. Bresnan, G. Miller and M. Halle (eds.), Linguistic Theory and Psychological Reality (pp. 264-293). Cambridge, MA: MIT Press.

Carlson, G.N. & Tanenhaus, M.K. (1988). Thematic roles and language comprehension. In W. Wilkins (Ed.), Thematic Relations, 263-288. New York: Academic Press.

Chomsky, N. (1981). Lectures on the theory of government and binding. Dordrectht: Foris.

Chang, F., Dell, G.S., & Bock, K. (2006). Becoming syntactic. Psychological Review, 113, 234-272.

Cheung, H. (1998). The use of syntactic information in learning Chinese verbs. National Taiwan University Working Papers in Linguistics, 1.

Childers, J.B., & Tomasello, M. (2001). The role of pronouns in young children's acquisition of the English transitive construction. Developmental Psychology, 37, 739-748.

Choi, Y., Arunachalam, S., Song, H., Choi, Y., & Trueswell, J.C. (2009). Syntactic bootstrapping from the serial verb construction in Korean. Paper presented at the Biennial Meeting of Society for Research in Child Development, Denver, CO.

Clancy, P.M. (2003). The lexicon in interaction: Developmental origins of preferred argument structure in Korean. In J. W. Du Bois, L. E. Kumpf, & W.J. Ashby (eds.), Preferred argument structure: Grammar as architecture for function, 81-108. Amsterdam: John Benjamins.

Connor, M., Gertner, Y., Fisher, C., & Roth, D. (2008). Baby SRL: Modeling early language acquisition. Proceedings of the Annual Conference on Computational Natural Language Learning (CoNLL).

Cooper, R. M. (1974). The control of eye fixation by the meaning of spoken language: A new methodology for the real-time investigation of speech perception, memory, and language processing. Cognitive Psychology, 6, 84-107.

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2008). Young German children's early syntactic competence: A preferential looking study. Developmental Science, 11, 575–582.

Dowty, D. (1991). Thematic proto-roles and argument selection. Language, 67, 547-619.

Fenson, L., Pethick, S., Renda, C., Cox, J.L., Dale, P.S., & Reznick, J.S. (2000). Short-form version of the MacArthur Communicative Development Inventories. Applied Psycholinguistics, 21, 95-115.

Fernandes, K.J., Marcus, G.F., DiNubila, J.A., & Vouloumanos, A. (2006). From semantics to syntax and back again: Argument structure in the third year of life. Cognition, 100, B10-B20.

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. Cognitive Psychology, 47, 164-203.

Fillmore, C. J. (1968). The case for case. In E. Bach & R. T. Harms (Eds.), Universals in linguistic theory (pp. 1-88). New York: Cambridge University Press.

Fisher, C. (1996). Structural limits on verb mapping: The role of analogy in children's interpretations of sentences. Cognitive Psychology, 31, 41-81.

Fisher, C. (2000). From form to meaning: A role for structural analogy in the acquisition of language. In H. W. Reese (Ed.), Advances in Child Development and Behavior, 1-53. New York: Academic Press.

Fisher, C. (2002a). Structural limits on verb mapping: The role of abstract structure in 2.5-year-olds interpretations of novel verbs. Developmental Science, 5, 55-64.

Fisher, C. (2002b). The role of abstract syntactic knowledge in language acquisition: A reply to Tomasello (2000). Cognition, 82, 259-278.

Fisher, C., & Gleitman, L.R. (2002). Language acquisition. In H. Pashler (Series Ed.), R. Gallistel (Volume Ed), Steven's handbook of experimental psychology (3rd ed.), Vol. 3: Learning, motivation, and emotion (pp. 445-496). New York: Wiley.

Fisher, C., Gleitman, G., & Gleitman, L. R. (1991). On the semantic content of subcategorization frames. Cogntive Psychology, 23, 331-392.

Fisher, C., Hall, D.G., Rakowitz, S., & Gleitman, L. (1994). When it is better to receive than to give: Syntactic and conceptual constraints on vocabulary growth. Lingua, 92, 333-375.

Fisher, C., Klinger, S.L., & Song, H. (2006). What does syntax say about space? 26-month-olds use sentence structure to learn new prepositions. Cognition, 101, B19-B29.

Ganea, P.A. (2005). Contextual factors affect absent reference comprehension in 14-month-olds. Child Development, 76, 989-998.

Ganea, P.A., Shutts, K., Spelke, E.S., & DeLoache, J.S. (2007). Thinking of things unseen: Infants' use of language to update mental representations. Psychological Science, 18, 734-739.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity and early word learning. In M. Bowerman & S. C. Levinson (Eds.), Language acquisition and conceptual development (pp. 215-256). New York: Cambridge University Press.

Gertner, Y. (2007, November). Not all transitive subjects are agents: Exploring 23-month-olds' understanding of transitive sentences. Paper presented at the Boston University Conference on Language Development, Boston, MA.

Gertner, Y., & Fisher, C. (2009). Predicted errors in children's early sentence comprehension. Manuscript under review.

Gertner, Y., Fisher, C., & Eisengart, J. (2006). Learning words and rules: Abstract knowledge of word order in early sentence comprehension. Psychological Science, 17, 684-691.

Gleitman, L. (1990). Structural sources of verb learning. Language Acquisition, 1, 1-63.

Gleitman, L. R., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. C. (2005). Hard words. Language Learning and Language Development, 1, 23-64.

Goldberg, A. (1995). Constructions: A Construction Grammar approach to argument structure. Chicago, IL: Univeristy of Chicago Press.

Goldberg, A. (1999). The emergence of argument structure semantics. In B. MacWhinney (ed.), The emergence of language (197-212). Mahwash, NJ: Lawrence Erlbaum Publications.

Goldberg, A. (2006). Constructions at work: The nature of generalization in language. Oxford: Oxford University Press.

Göksun, T., Küntay, A., & Naigles, L.R. (2008). Turkish children use morphosyntactic bootstrapping in interpreting verb meaning. Journal of Child Language, 35, 291-323.

Goldin-Meadow, S. (2003). The resilience of language. New York: Psychology Press.

Golinkoff, R. M., Hirsh-Pasek, K., Cauley, K. M., & Gordon, L. (1987). The eyes have it: Lexical and syntactic comprehension in a new paradigm. Journal of child language, 14, 23-45.

Gómez, R. & Gerken, L. (1999). Artificial grammar learning by 1-year-olds leads to specific and abstract knowledge. Cognition, 70, 109-135.

Gordon, P. (2003). The origin of argument structure in infant event representations. Proceedings of the 27th Boston University Conference on Language Development. Sommerville, MA: Cascadilla Press.

Gordon, P. & Chafetz, J. (1990). Verb-based versus class-based accounts of actionality effects in children's comprehension of passives. Cognition, 36, 227-254.

Grimshaw, J. (1993, April). Semantic structure and semantic content: A preliminary note. Paper presented at the conference on Early Cognition and the Transition to Language. University of Texas at Austin.

Grimshaw, J. (1994). Lexical reconciliation. Lingua, 92, 411-430.

Hirsh-Pasek, K. & Golinkoff, R. (1996). The origins of grammar: Evidence from early language comprehension (pp. 73-98). Cambridge, MA: The MIT Press.

Hirsh-Pasek, K., Golinkoff, R., & Naigles, N. (1996). Young children's use of syntactic frames to derive meaning. In K. Hirsh-Pasek and R. Golinkoff (eds.), The origins of grammar: Evidence from early language comprehension (pp. 123-158). Cambridge, MA: The MIT Press.

Kidd, E., Bavin, E., & Rhodes B. (2001) Two year-olds' knowledge of verbs and argument structures. In M. Almgren, A. Barreña, M-J. Ezeizabarrena, I. Idiazabal, & B. MacWhinney (Eds.) Research on child language acquisition (pp. 1368-1382). Cascadilla Press.

Kim, Y. (2000). Subject/object drop in the acquisition of Korean: A cross-linguistic comparison. Journal of East Asian Linguistics, 9, 325-351.

Lan, C. C. C. (1999). The acquisition of verb argument structures in young Cantonese-speaking children. Unpublished dissertation. University of Hong Kong.

Landau, B., & Gleitman, L.R. (1985). Language and experience: Evidence from the blind child. Cambridge, MA: Harvard University Press.

Lee, J., & Naigles, L. (2005). Input to verb learning in Mandarin Chinese: A role for syntactic bootstrapping. Developmental Psychology, 41, 529-540.

Lee, J., & Naigles, L. (2008). Mandarin learners use syntactic bootstrapping in verb acquisition. Cognition, 106, 1028-1037.

Levin, B. & Rappaport Hovav, M. (2005). Argument realization. New York: Cambridge University Press.

Leslie, A. M., & Keeble, S. (1987). Do six-month-old infants perceive causality? Cognition, 25, 265-288.

Li, C., & Thompson, S. (1981). Mandarin Chinese: A functional reference grammar. Berkeley, CA: University of California Press.

Lidz, J., & Gleitman, L. (2004). Argument structure and the child's contribution to language learning. Trends in Cognitive Science, 8, 157-161.

Lidz, J., Gleitman, L., & Gleitman, H. (2003). Understanding how input matters: Verb learning and the footprint of universal grammar. Cognition, 87, 151-178.

Oakes, L. M., & Cohen, L. B. (1990). Infant perception of a causal event. Cognitive Development, 5, 193-207.

Marcus, G. Vijayan, S., Bandi Rao, S., & Vishton, P. (1999). Rule learning by seven-month-old infants. Science, 283, 77-80.

Maratsos, M., & Chalkley, M.A. (1980). The internal language of children's syntax: the ontogenesis and representation of syntactic categories. In: Nelson, K. (Ed.), Children's language, Vol. 2 (pp. 127-213). New York: Gardner Press.

McClure, K., Pine, J.M., & Lieven, E.V.M. (2006). Investigating the abstractness of children's early knowledge of argument structure. Journal of Child Language, 33, 693-720.

Mintz, T. (2006). Finding the verbs: Distributional cues to categories available to young learners. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), Action meets words: How children learn verbs (pp. 31-63). Oxford: Oxford University Press.

Naigles, L. (1990). Children use syntax to learn verb meanings. Journal of child language, 17, 357-374.

Naigles, L. (1996). The use of multiple frames in verb learning via syntactic bootstrapping. Cognition, 58, 221-251.

Naigles, L. R., & Hoff-Ginsberg, E. (1995). Input to verb learning: Evidence for the plausibility of syntactic bootstrapping. Developmental Psychology, 31, 827-837.

Naigles, L., & Kako, E.T. (1993). First contact in verb acquisition: defining a role for syntax. Child development, 64, 1665-1687.

Naigles, L.R., & Maltempo, A. (2007). The boundaries of syntactic bootstrapping: A role for pragmatics. Paper presented at the Biennial Meeting of Society for Research in Child Development, Boston, MA.

Naigles, L.R., & Swensen, L.D. (2007). Syntactic supports for word learning. In E. Hoff & M. Shatz (Eds.), Blackwell Handbook of Language Development (pp. 212-222). New York: Wiley-Blackwell.

Narasimhan, B., Budwig, N., & Murty, L. (2005). Argument realization in Hindi caregiver-child discourse. Journal of Pragmatics, 37, 461-495.

Olguin, R., & Tomasello, M. (1993). Twenty-five-month-old children do not have a grammatical category of verb. Cognitive Development, 8, 245-272.

Papafragou, A., Cassidy, K., & Gleitman, L. (2007). When we think about thinking: The acquisition of belief verbs. Cognition, 105, 125-165.

Pinker, S. (1989). Learnability and cognition. Cambridge, MA: MIT Press.

Quine, W.V.O. (1960). Word and object. Cambridge, MA: MIT Press.

Rispoli, M. (1989). Encounters with Japanese verbs: Caregiver sentences and the categorization of transitive and intransitive action verbs. First Language, 9, 57-80.

Rispoli, M. (1992). Discourse and the acquisition of eat. Journal of Child Language, 19, 581-595.

Rispoli, M. (1995). Missing arguments and the acquisition of predicate meanings. In M. Tomasello & W. E. Merriman (Eds.), Beyond names for things: Young children's acquisition of verbs (pp. 331-352). Hillsdale, NJ: Lawrence Erlbaum.

Rochat, P., Striano, T., & Morgan, R. (2004). Who is doing what to whom? Young infants' developing sense of social causality in animated displays. Perception, 33, 355-369.

Saffran, J., Aslin, R., & Newport, E. (1996). Statistical learning by 8-month-olds. Science, 274, 5294-5301.

Santelmann, L.M., & Jusczyk, P.W. (1998). Sensitivity to discontinuous dependencies in language learners: Evidence for limitations in processing space. Cognition, 69, 105-134.

Saylor, M.M. (2004). 12- and 16-month-old infants recognize properties of mentioned absent things. Developmental Science, 7, 599-611.

Schlottman, A., & Surian, L. (1999). Do 9-month-old infants perceive causation-at-a-distance? Perception, 28, 1105-1113

Schmerling, S. (1972). Subjectless sentences and the notions of surface structure. In C. Corum, T.C. Smith, and A. Weiser (eds.), Papers from the Ninth Regional Meeting of the Chicago Linguistic Soceity (577-586). Chicago: University of Chicago Press.

Scott, R. M., & Fisher, C. (2009). 2-year-olds use distributional cues to interpret transitivity-alternating verbs. Language and Cognitive Processes, 24, 777-803..

Seidl, A., Hollich, G., & Jusczyk, P. (2003). Early comprehension of subject and object wh-questions. Infancy, 4, 423-436.

Shady, M.,Gerken, L.A., & Jusczyk, P. (1995). Some evidence of sensitivity to prosody and word order in ten-month-olds. In D. MacLaughlin and S. McEwan (eds.), Proceedings of the 19th Boston University Conference on Language Development, Vol.2, 553-562. Sommerville, MA: Cascadilla Press.

Shimpi, P. M., Gámez, P. B., Huttenlocher, J., & Vasilyeva, M. (2007). Syntactic priming in 3- and 4-year-old children: Evidence for abstract representations of transitive and dative forms. Developmental Psychology, 43, 1334-1346.

Skarabela & Allen, 2002

Snedeker, J., & Trueswell, J. (2004). The developing constraints on parsing decisions: The role of lexical-biases and referential scenes in child and adult sentence processing. Cognitive Psychology, 49, 238-299.

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J.C. (1995). Integration of visual and linguistic information in spoken language comprehension. Science, 268, 1632-1634.

Tardif, T., Fletcher, P., Liang, W.L., & Zhang, Z.X. (July, 2002). Nouns and verbs in children's early vocabularies: A cross-linguistic study of the MacArthur Communicative Development Inventory in English, Mandarin, and Cantonese. Paper presented at Joint Conference of International Association for the Study of Child Language and Society for Research in Communication Disorders. Madison, WI, July 2002.

Thothathiri, M., & Snedeker, J. (2008). Syntactic priming during language comoprehension in three- and four-year-old children. Journal of Memory and Language, 58, 188-213.

Tomasello, M. (2000). Do young children have adult syntactic competence? Cognition, 74, 209-253.

Tomasello, M. (2003). Constructing a language: A usage-based theory of language acquisition. Cambridge, MA: Harvard University Press.

Tomasello, M., & Abbott-Smith, K. (2002). A tale of two theories: Response to Fisher. Cognition, 83, 207-214.

Tomasello, M., & Brooks, P. (1998). Young children's earliest transitive and intransitive constructions. Cognitive Linguistics, 9, 379-395.

Valian, V. (1991). Syntactic subjects in the early speech of American and Italian children. Cognition, 40, 21-81.

Wang, Q., Lillo-Martin, D., Best, C. T., & Levitt, A. (1992). Null subject versus null object: Some evidence from the acquisition of Chinese and English. Language Acquisition, 2, 221-254.

Waxman, S., & Booth, A. (2001). Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. Cognitive Psychology, 43, 217-242.

Woodward, A. L. (1999). Infants' ability to distinguish between purposeful and non-pursposeful behaviors. Infant Behavior and Development, 22, 145-160.

Wykes, T., & Johnson-Laird, P.N. (1977). How do children learn the meanings of verbs? Nature, 268, 326-327.

Yuan, S., & Fisher, C. (2009). "Really? She blicked the baby?": Two-year-olds learn combinatorial facts about verbs by listening. Psychological Science, 20, 619-26. (Chapter 4).

Yuan, S., Fisher, C., Gertner, Y., & Snedeker, J. (2007, March). Participants are more than physical bodies: 21-month-olds assign relational meaning to transitive novel verbs. Paper presented at the Biennial Meeting of Society for Research in Child Development, Boston, MA.

Yuan, S., Fisher, C., Snedeker, J., & Gertner, Y. (in preparation). Counting the nouns and participants: Linking sentence- and event-representations in early verb learning.

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Education

2009 Ph.D. University of Illinois; Developmental Psychology
Thesis: Integrating sentence-structural and event information in early verb learning

2005 M.A. University of Illinois; Developmental Psychology

2001 M.Ed. Harvard University Graduate School of Education; Human Development and Psychology

2000 B.A. Brown University; Magna cum Laude, Applied Mathematics and Economics

Research Interests

Language acquisition and processing, physical reasoning in infancy

Honors and Awards

2008 McVicker Hunt Award for Excellence in Graduate Research and Scholarship, University of Illinois
2008 Conference Travel Award, University of Illinois
2008 Graduate Student Award, International Conference on Infant Studies
2007 Conference Travel Award, University of Illinois
2007 Dissertation Travel Award, University of Illinois
2005 Paula Menyuk Award, Boston University Conference on Language Development
2003 National Science Foundation Graduate Fellowship Honorable Mention
2003 Conference Travel Award, University of Illinois
2000 Harvey Almy Baker Fellowship, Brown University
2000 Phi Beta Kappa, Brown University
2000 Omicron Delta Epsilon, Brown University Department of Economics Honor Society

Research Experience

2003-2008	Graduate research assistant in Language Acquisition Department of Psychology, University of Illinois with Cynthia Fisher
2004-2008	Graduate research assistant in Infant Cognition Department of Psychology, University of Illinois with Renée Baillargeon
2001-2003	Research assistant in Language Acquisition (full-time) Department of Psychology, Harvard University with Jesse Snedeker
2000-2001	Research assistant in Cultural and Educational Studies Graduate School of Education, Harvard University with Marcelo and Carola Suárez-Orozco
1999-2000	Research assistant in Cross-cultural Developmental Studies Education Department, Brown University with Jin Li

Publications

Yuan, S., & Fisher, C. (2009). "Really? She blicked the baby?": Two-year-olds learn combinatorial facts about verbs by listening. *Psychological Science, 20,* 619-626.

Fisher, C., Gertner, Y., Scott, R. M., & Yuan, S. (2009). Syntactic bootstrapping. To appear in *Wiley Interdisciplinary Reviews: Cognitive Science.*

Baillargeon, R., Wu, D., Yuan, S., & Luo, Y. (2009). Young infants' expectations about self-propelled objects. In B. Hood & L. Santos (Eds.), *The Origins of Object Knowledge* (pp. 285-352). New York: Oxford University Press.

Snedeker, J.. & Yuan, S. (2008). Effects of prosodic and lexical constraints on parsing in young children (and adults). *Journal of Memory and Language, 58,* 574-608.

Baillargeon, R., Li, J., Ng, W., & Yuan, S. (2008). An account of infants' physical reasoning. In A. Woodward & A. Needham (Eds.), *Learning and the infant mind* (pp. 66-116). New York: Oxford University Press.

Yuan, S. & Fisher, C. (2006). "Really? He blicked the cat?": Two-year-olds learn distributional facts about verbs in the absence of a referential context. *Proceedings of the 30th Annual Boston University Conference on Language Development.* Boston, MA: Cascadilla Press.

Snedeker, J., Li, P. & Yuan, S. (2003). Cross-cultural differences in the input to early word learning. *Proceedings of the Twenty-Fifth Annual Conference of the Cognitive Science Society*. Mahwah, NJ: Erlbaum.

Manuscripts in Preparation

Yuan, S., Fisher, C., Snedeker, J., & Gertner, Y. Counting the nouns: Simple structural cues to verb learning.

Yuan, S., Fisher, C., Li, N., Cheung, H., Chen, S-Y., Lin, J., & Tsao, F-M. Mandarin-speaking 2-year-olds use simple syntactic cues in interpreting novel verbs.

Yuan, S., & Baillargeon, R. Exposure to weight information primes 11-month-old infants to detect support violations.

Yuan, S., Baillargeon, R., Raschke, H., & Keeler, M. The development of infants' reasoning about the support of asymmetrical objects.

Conference Presentations

Yuan, S., & Fisher, C. (2009, April). 19-month-olds use simple syntactic cues in verb learning. Paper presented at the Biennial Meeting of the Society for Research in Child Development Biennial Meeting, Denver, CO.

Yuan, S., & Baillargeon, R. (2009, April). The development of infants' reasoning about the support of asymmetrically-shaped objects. Paper presented at the Biennial Meeting of the Society for Research in Child Development Biennial Meeting, Denver, CO.

Yuan, S. (2008, November). 2-year-olds learn and retain combinatorial facts about a novel verb over a delay. Poster presented at the Annual Boston University Conference on Language Development, Boston, MA.

Yuan, S., Scott, R., Fisher, C., & Mintz, T. (2008, March). 21-month-olds learn distributional facts about a new verb via listening experience. Poster presented at the Biennial International Conference on Infant Studies. Vancouver, B.C., Canada.

Yuan, S., & Baillargeon, R. (2008, March). 2.5-month-olds hold different expectations about the support of inert and self-propelled objects. Poster presented at the Biennial International Conference on Infant Studies. Vancouver, B.C., Canada.

Yuan, S., Li, N., Cheung, H., Fisher, C., Chen, S-Y., Lin, J., & Tsao, F-M. (2007, November). Mandarin-speaking 2-year-olds use simple syntactic cues in interpreting novel verbs. Poster presented at the Annual Boston University Conference on Language Development, Boston, MA.

Yuan, S., Fisher, C., Gertner, Y., & Snedeker, J. (2007, March). Participants are more than physical bodies: 21-month-olds assign relational meaning to transitive novel verbs. Paper presented at the Biennial Meeting of the Society for Research in Child Development Biennial Meeting, Boston, MA.

Yuan, S., & Baillargeon, R. (2006, April). Holding heavy and light objects primes 11-month-old infants to attend to weight information in support events. Paper presented at an invited symposium at the Conference on Human Development, Louisville, KY.

Yuan, S. & Fisher, C. (2005, November). "Really? He blicked the cat?": Two-year-olds learn distributional facts about verbs in the absence of a referential context. Paper presented at the Annual Boston University Conference on Language Development, Boston, MA.

Yuan, S., Baillargeon, R., & Fisher, C. (2005, April). Priming infants to attend to weight information in support events. Poster presented at the Society for Research in Child Development Biennial Meeting, Atlanta, GA.

Yuan, S., Li, P., Huang, B. & Snedeker, J. (2003, November). Cross-cultural differences in the input to early word learning: Word-to-world mapping in Mandarin and English. Paper presented at the Boston University Conference on Language Development, Boston, MA.

Snedeker, J., Li, P., & Yuan, S. (2003, August). Cross-cultural differences in the input to early word learning. Paper presented at the Cognitive Science Society Conference, Boston, MA.

Snedeker, J. & Yuan, S. (2003, April). Mixing up the words and the melody: Children's use of lexical and prosodic information in real-time language comprehension. Paper presented at the Society of Research in Child Development, Tampa, FL.

Snedeker, J., & Yuan, S. (2003, March). Is it the words or the melody? The use of lexical and prosodic information in children's parsing. Paper presented at the Annual CUNY Conference on Human Sentence Processing, Cambridge, MA.

Snedeker, J., Yuan, S., & Martin, I. (2002, November). A limited role for prosody in children's online sentence processing. Paper presented at the Annual Boston University Conference on Language Development, Boston, MA.

Li, J., Yue, X., & Yuan, S. (2001, April). Individual self and social self in learning among Chinese adolescents. Paper presented at the Biennial Meeting of the Society of Research in Child Development, Minneapolis, MN.

Brownbag Talks (at University of Illinois)

Yuan, S. (2007). From sentence to verb meaning: Children's use of simple syntactic cues in early verb learning. Developmental Division Brownbag Series, November 30.

Yuan, S. (2007). Participants are more than physical bodies: 21-month-olds assign relational meaning to novel transitive verbs. Developmental Division Brownbag Series, March 31.

Yuan, S. (2007). Counting the nouns: Use of simple structural cues in early verb learning. Graduate Student Seminar, Beckman Institute, February 21.

Yuan, S. (2006). Holding heavy and light objects primes 11-month-old infants to attend to weight information in support events. Developmental Division Brownbag Series, April 28.

Yuan, S. (2006). "Really? He blicked the cat?" Two-year-olds learn distributional facts about verbs in the absence of a referential context. Language Processing Brownbag Series, October, 27.

Yuan, S. (2005). Will it fall or remain stable? Infants' use of weight information in support events. Developmental Division Brownbag Series, Department of Psychology, March 18.

Yuan, S. (2004). Learning verbs by counting nouns. Developmental Division Brownbag Series, April 30.

Teaching Experience and Mentoring

2008 (spring) Course instructor
Child Psychology
University of Illinois

2008 (spring) Mentor for undergraduate advanced research in psychology
Project title: "2-year-olds learn verbs' selectional restrictions via listening"
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2008 (spring) Guest lecturer
"Infant Preparations for Language" in Child Psychology
Instructor: Elizabeth Moorman
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2006 (spring) Teaching assistant
Child Psychology
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