Available online at www.sciencedirect.com
ScienceDirect
Journal of Memory and Language 58 (2008) 188–213
Journal of Memory and Language
www.elsevier.com/locate/jml

Syntactic priming during language comprehension in three- and four-year-old children

Malathi Thothathiri *, Jesse Snedeker

Department of Psychology, Harvard University, William James Hall, 33 Kirkland Street, Cambridge, MA 02138, USA

Received 15 September 2006; revision received 21 June 2007
Available online 29 August 2007

Abstract

We report two sets of experiments that demonstrate syntactic priming from comprehension to comprehension in young children. Children acted out double-object and prepositional-object dative sentences while we monitored their eye movements. We measured whether hearing one type of dative as a prime influenced children's online interpretation of subsequent dative utterances. In target sentences, the onset of the direct object noun was consistent with both an animate recipient and an inanimate theme, creating a temporary ambiguity in the argument structure of the verb (double-object e.g., *Show the **hor**se the book*; prepositional-object e.g., *Show the **hor**n to the dog*). The first set of experiments demonstrated priming in four-year-old children (M = 4.1), both when the same verb was used in prime and target sentences (Experiment 1a) and when different verbs were used (Experiment 1b). The second set found parallel priming in three-year-old children (M = 3.1). These results indicate that young children employ abstract structural representations during online sentence comprehension.

Keywords: Syntactic priming; Structural priming; Syntax; Comprehension; Children

A perennial question in theoretical linguistics is how to characterize the relations between syntactic roles, semantic roles, and our knowledge of specific predicates (see e.g., Baker, 1988; Goldberg, 1995; Grimshaw, 1990; Jackendoff, 2002). Thus it is unsurprising that the history of language acquisition has been marked with parallel questions about the developmental priority and interaction of these three kinds of knowledge. Any account of these relations must come to grips with two facts. First, across predicates and languages, there are systematic linkages between meaning and syntactic structure (Baker, 1988; Dowty, 1991; Fillmore, 1968; Fisher, Gleitman, & Gleitman, 1991; Jackendoff, 2002; Levin, 1993). For example events of transfer are typically encoded by verbs taking three arguments, while self-generated motions are encoded by intransitive verbs. Second, although these linkages are widespread and systematic, they do not fully predict the syntactic position of arguments in all utterances. Two very similar propositions can be expressed using quite different surface syntactic forms, depending on the verb, its morphological form and factors such as discourse structure and the phonological weight of constituents (1). Since much of this variation is linked to differences between verbs, all viable theories make use of lexically-specific information (though they vary in whether that information is

* Corresponding author.
E-mail address: malathi@wjh.harvard.edu (M. Thothathiri).

0749-596X/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.jml.2007.06.012

syntactic or semantic and in whether it directly generates structure or serves as a filter on possible structures).

1 a. The real estate agent gave Sara a calendar.
  b. The real estate agent gave a calendar to Sara.
  c. Sara received a calendar from the real estate agent.

While all theories of language acquisition acknowledge these two facts, they differ in which of the two they take to be primary. The systematicity of syntactic–semantic correspondences has led many to suggest that the linkages between meaning and structure are innate properties of universal grammar which play a role in language acquisition (Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman, 1990; Grimshaw, 1981; Pinker, 1984). One such theory is Pinker's semantic bootstrapping hypothesis (1984). Pinker proposed that children come to the task of language acquisition with (1) a set of thematic roles (e.g., agent, patient, goal); (2) a set of syntactic functions (e.g., subject, object, object of preposition), and (3) default rules for linking one to the other. These linking rules drive the learning process for canonical verbs (e.g., *chase*). For non-canonical verbs (e.g., *receive*), children learn the correct subcategorization frames by performing distributional analyses over the input.

In contrast, usage-based theories place lexically-specific information at the center of language acquisition (Goldberg, 1995; Tomasello, 1992). For example, according to Tomasello's verb island hypothesis (1992) children initially analyze each predicate as an isolated grammatical island with open argument positions that can be freely filled with nominals, similar to the pivot grammars proposed in the 1960s by Braine (1963) and McNeill (1966). Gradually children begin to notice overlap in the semantic functions that are assigned to these fillers, and in their morphological marking or position relative to the verb. This observed overlap leads them to form broader semantic categories (such as agent and theme), broader syntactic categories (such as verb, subject and object), and generalizations about their relationship.

There are two critical ways in which the semantic bootstrapping hypothesis differs from the verb island hypothesis. First, the semantic bootstrapping hypothesis proposes that novice language learners represent utterances in terms of broad semantic and syntactic categories that allow them to make generalizations from one verb to another. Second, the semantic bootstrapping hypothesis proposes innate default mappings between these semantic and syntactic primitives. The two features are partially independent. While innate mappings between syntax and semantics presuppose the availability of abstractions of roughly the same scope as the target grammar, the converse need not be true. Abstractions such as verb, agent, subject, theme and object, may guide structural generalization from the beginning even if the mappings between syntactic and semantic roles have to be learned.

Many of the arguments against semantic bootstrapping target the viability of innate syntax-to-semantics mappings, disputing either their universality or their role in development. For example, Levin (1983) and Marantz (1984) suggest that in deep ergative languages the patient is expressed as the subject while the agent is expressed as the direct object (but see Baker, 1997; Dixon, 1994). Bowerman (1990) has argued that children's early language production provides no evidence that canonical argument mappings are acquired earlier than non-canonical ones. In contrast, the notion that children's early grammars employ broad categories is shared by a diverse set of theories, including domain-general proposals. For example, Brown (1973), Bowerman (1973), Braine (1976), and Slobin (1985) all suggested that early child language was organized around conceptual categories (e.g., action, actor) which serve as an entry point into syntax. Braine (1992) grants the novice structured semantic representations that include categories such as predicate and argument. Goldberg (2006) emphasizes the learning of syntax–semantics mappings but nevertheless suggests that children have semantic generalizations (such as actor) and syntactic slots (like prepositional phrase) from very early on. While these theories vary in many respects, they all posit an early grammar with abstract categories that support generalizations across verbs. This contrasts with the verb island hypothesis which explicitly claims that early grammars lack such categories before three- to three-and-a-half years of age. For example, Tomasello (2000a, p. 214): states: "Other than the categorization of nominals, nascent language learners possess no other linguistic abstractions or forms of syntactic organization." Savage, Lieven, Theakston, and Tomasello (2003, p. 565) state: "Together, all findings point to the conclusion that the linguistic representations underlying young children's earliest syntactic constructions are lexically specific, with more abstract representations emerging only gradually during the preschool years."

In the present study, we leave aside the question of universal syntax-to-semantics mappings, and take an initial step towards exploring the other issue, namely, whether young children have representations that support generalizations across verbs. Specifically, we ask whether three- and four-year-old children show a form of structural priming that cannot be captured by a linguistic system that is limited solely to isolated, verb-specific representations. In the remainder of this introduction we briefly discuss findings from other methods for exploring the scope of children's structural generalizations, then we introduce the structural priming

technique, and summarize the mixed findings from earlier studies employing production priming in children.

Novel-verb generalization as a window onto grammatical representations

Observational studies of spontaneous speech have sometimes been cited as evidence for early abstractions (e.g., Bowerman, 1973). However, Tomasello (1992) pointed out that in the absence of a complete record of children's input, we cannot be sure whether children are generalizing or merely imitating the structures used by others around them. This issue is better addressed by experimental studies using novel verbs. In the past decade, a series of novel-verb production studies have shown that children under 3.5 years of age primarily use new verbs in ways that mimic the input, failing to generalize argument structure alternations from one verb to another (see Tomasello, 2000b; for a review). For example, 2- and 2.5-year-old children who heard a novel verb used in either a transitive or an intransitive construction (e.g., *The puppy is meeking the ball* or *The ball is meeking*) preferred to use the construction modeled by the adult almost 90 percent of the time despite discourse pressures to the contrary (Tomasello & Brooks, 1998). These results have been used to argue that children's early sentence-level constructions are verb-specific, and that abstract verb-general constructions are constructed gradually during the preschool years (see also Brooks & Tomasello, 1999a). But the pattern of findings can be used to support a quite different interpretation. In a production task with novel dative verbs, Conwell and Demuth (2007) found a similar preference for the modeled over the unmodeled construction in three-year-olds. However, because the children used the unmodeled construction significantly more than chance, the authors concluded that the data provided evidence *in favor of* early abstract representations.

An additional empirical challenge to the verb island hypothesis comes from novel-verb studies using comprehension tasks. These studies suggest that young children can use broad semantic-syntactic mappings to interpret the thematic roles assigned by a novel verb. For example, children as young as 20 months prefer to map transitive sentences to caused motion events (rather than self-generated motion events) but show no such preference for intransitive sentences (Fisher, 2002a; Yuan, Fisher, Gertner, & Snedeker, 2007). These mappings also guide children's interpretation of reversible transitives. By 21 months of age children interpret the subject of a transitive sentence with a novel verb as the agent of the action (Fisher, 2000; Gertner, Fisher, & Eisengart, 2006; see also Fernandes, Marcus, DiNubila, & Vouloumanos, 2006).

How can we reconcile the productivity present in the novel-verb comprehension studies with the conservatism observed in the novel-verb production studies? Most authors suggest that one set of findings is primary while the other largely reflects task-specific abilities or limitations. For example, Tomasello and colleagues have suggested that the preferential-looking studies may reflect fragile, incomplete or emerging representations that initially play little role in everyday comprehension and production (see e.g., Savage et al., 2003; Tomasello & Akhtar, 2003). Fisher (2002b) makes the converse argument, noting problems with interpreting low productivity during novel-verb production as evidence for the absence of abstract representations. The set of constructions in which a verb can participate depends on a complex set of semantic constraints (Levin, 1993). For example, the causative alternation, employed by Tomasello and Brooks (1998), is restricted to only those motion verbs that encode a manner of motion which is externally caused. This suggests two reasons why a child who *has* abstract representations of argument structure might be reluctant to extend novel verbs to unattested constructions (but see Tomasello & Abbot-Smith, 2002). First, she might have limited knowledge of the semantic constraints that govern the alternation. Second, she could know the constraints but be uncertain about the meaning of the verb. Previous research suggests that extracting the meaning of a novel verb from a visual scene is difficult even for adults (Gillette, Gleitman, Gleitman, & Lederer, 1999; Snedeker & Gleitman, 2004). For example, children in the Tomasello and Brooks (1998) experiment may have failed to infer that a novel verb referred to the manner of a caused motion and thus could participate in the alternation, concluding instead that it encoded the theme's direction of motion (e.g., *rise*, which appears only in the intransitive), or indirect contact between the agent and theme (e.g., *hit*, which appears only in the transitive).

In sum, the findings from novel-verb comprehension and production studies have led to divergent conclusions and controversy. Children may fail at the novel-verb production tasks because they do not understand exactly what the verb means. Or they may succeed in the novel-verb comprehension studies by employing task-specific strategies or emergent generalizations that may play little role in daily language use.

Some have even questioned the relevance of the novel-verb paradigm for studying syntax acquisition. For example, Ninio (2005) suggests that generalization paradigms place children in an unnatural situation, forcing them to make inferences about the structures that a verb can appear in, when they would ordinarily be able learn these facts by direct observation. Furthermore, she argues that success in novel-verb tasks does not necessarily demonstrate that children have linguistic representations which are abstract. She suggests that children's

grammatical knowledge is lexically specific and concrete, but under unusual circumstances, like those in the generalization studies, knowledge of one verb can be extended to another through a process of structural analogy.

The impact of this argument depends on our conception of analogy. Consider a child who hears "The bunny is gorping the duck" while watching two videos in which one actor pulls another by the feet. If she transfers structural knowledge from known verbs to the novel verb by virtue of the structure of the utterance or the fact that they are all *verbs*, then this process would posit precisely the kind of generalizations that the verb island hypothesis denies. But what if the child simply translates the novel verb into a known form that has the same apparent meaning (e.g., *gorp* means *pull*)? This would allow her to apply item-specific knowledge without invoking any higher-level linguistic categories. In sum, knowing that knowledge is transferred from known verbs to a novel verb leaves open questions about the representations that underlie this transfer and the knowledge that children draw upon in their comprehension and production of known words. Below, we discuss how structural priming can help shed light on children's workaday structural representations.

Structural priming and children's representations

Structural priming refers to the effect that the use of a particular construction or structure has on subsequent uses of the same structure (Bock, 1986). For example, adults are more likely to use a passive sentence after a passive sentence than after an active sentence. This priming is *structural* in that it occurs even when the meanings of the prime sentences are controlled and the prime and target sentences have no content words in common. This technique has some advantages over the methods reviewed above. First, unlike naturalistic observation, we can experimentally control the contexts that children are placed in and manipulate the linguistic input given to them. Second, unlike studies using novel verbs, we can study how children use *known* verbs under controlled conditions. As mentioned above, success at a novel-verb generalization task is compatible with reliance on lexically-specific representations for comprehension and production, supplemented by analogical problem-solving strategies. By looking for abstract structural priming amongst known verbs (for which children could presumably possess adequate lexically-specific representations), we can better evaluate the importance of abstract representations in children's everyday language use. A third advantage is that we can compare priming when the same verb is used across sentences to priming when different verbs are used. This can elucidate whether children are concurrently using both lexical and abstract representations, which may help reconcile seemingly contradictory findings in the language acquisition literature, namely, that children possess early abstract representations but still use verbs in highly item-specific ways.

With adults, production-priming has been demonstrated in a variety of tasks. These include picture description (Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992), sentence recall (Potter & Lombardi, 1998), written sentence completion (Pickering & Branigan, 1998), spoken sentence completion (Branigan, Pickering, Stewart, & McLean, 2000), and dialogue with a confederate (Branigan, Pickering, & Cleland, 2000). The structures tested include the transitive alternation (Bock et al., 1992), the dative alternation (Pickering & Branigan, 1998), the locative alternation (Chang, Bock, & Goldberg, 2003) and relative clause attachment ambiguities (Scheepers, 2003). These results show that adults use abstract structural representations during language production. In addition, under some conditions there is stronger priming when there is lexical overlap between the prime and target than when there is no overlap, suggesting that adults are using both lexically-specific and abstract representations (Pickering & Branigan, 1998). In fact, in parallel comprehension tasks, there is consistent evidence for lexically-specific priming but not for abstract structural priming (Arai, Van Gompel, & Scheepers, 2005; Branigan, Pickering, & McLean, 2005; but see Scheepers & Crocker, 2004). The difference between production and comprehension priming has led some to propose that comprehension may be more lexically-driven than production (Arai et al., 2005).

Structural priming has only recently been used for the specific purpose of studying the nature of young children's representations. To date, the three published priming studies with children have all tested production using the picture description paradigm. In these studies, children either repeated or listened to a prime sentence uttered by the experimenter and then described a target picture. The first study compared passive and active transitive constructions (Savage et al., 2003). Children were assigned to either a high or a low lexical overlap condition. In the high overlap condition, prime sentences used pronouns that could potentially be repeated in the target descriptions (e.g., *It got pushed by it*). In the low overlap condition, prime sentences used nouns that could not be repeated in the target descriptions (e.g., *The bricks got pushed by the digger*). The main finding was that six-year-olds showed priming in both overlap conditions, but three- and four-year-olds showed priming in the high overlap condition only. The authors concluded that while six-year-olds have abstract representations, three- and four-year-olds rely primarily on lexically-specific representations involving pronouns

and some grammatical morphemes.[1] In contrast, Huttenlocher and colleagues found structural priming in four- and five-year-olds for both transitive and dative constructions (Huttenlocher, Vasilyeva, & Shimpi, 2004). The two studies differed in several respects, suggesting multiple explanations for the difference in findings. For example, the experimenter uttered each prime sentence four times in the first study and only once in the second. The first study excluded truncated passives as target responses; the second one did not. Critically, the four-year-olds in the Huttenlocher study (Experiment I: M = 4;8) were older than those in the Savage study (Experiment I: M = 4;2). In a subsequent study, Savage and colleagues found that increasing the number of different prime verbs strengthened priming effects in older four-year-old children (M = 4;11), confirming that by this age, priming is verb-general (Savage, Lieven, Theakston, & Tomasello, 2006). Recent unpublished reports of production priming in three-year-olds, complicate this picture. Gamez, Shimpi, and Huttenlocher (2005) found no structural priming of datives in a picture description task with 3.5- to 4.5-year-olds. In contrast, using a sentence-imitation task, Song and Fisher (2004) found robust structural priming in three-year-old children. In short, the findings for production–riming roughly converge with the findings of novel-verb production studies: in both cases older four-year-olds provide robust evidence of abstract structural representations, while the nature of three-year-olds' representations is more controversial.

The current study uses structural priming, but differs from previous studies in two important ways. First, our experiments examine priming during language comprehension rather than production. Since production tasks are often more difficult for children than comprehension tasks (Hirsh-Pasek & Golinkoff, 1996), this may provide a more sensitive measure of children's linguistic knowledge and allow us to test younger children. Indeed, studies that use preferential looking to measure the comprehension of novel verbs (e.g., Fisher, 2000) typically find evidence for argument structure abstractions at an earlier age than studies using production measures. Alternately, adult priming studies suggest that comprehension may be more lexically driven than production, raising the possibility that this might be the last place where abstract structure would become apparent. Second, the current study uses a visual-world paradigm that taps online sentence processing. We measure participants' eye movements while they listen to instructions and manipulate objects. Under these circumstances, eye movements to the objects are tightly linked to the unfolding utterances and are sensitive to lexical and structural processing in both adults (e.g., Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) and children (Snedeker & Trueswell, 2004; Snedeker & Yuan, in press; Trueswell, Sekerina, Hill, & Logrip, 1999). By using a technique with good temporal resolution, we can determine the locus of the priming effect and rule out alternate explanations that might apply to priming during production (see General discussion).

Experiment 1

In Experiment 1, we asked whether four-year-olds show within-verb priming (Experiment 1a) and across-verb priming (Experiment 1b). Critical instructions were double-object or prepositional-object dative sentences with the verb *give*. We chose to use the dative alternation for two reasons. First, a number of studies have concluded that by three years of age, children comprehend and produce both kinds of dative constructions (Campbell & Tomasello, 2001; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989). Second, the alternative dative constructions differ primarily in their syntactic structure and in the mappings between thematic roles and syntactic positions, and only slightly in meaning (if at all, see Baker, 1997). Thus, priming using datives offers a reasonably clear case of structural priming independent of semantics.

Participants

All the children in this and subsequent experiments were native speakers of English from the Boston area and none participated in more than one session. Twenty four-year-olds (4;0–4;6, mean age = 4;1, 11 female) participated in Experiment 1a. Data from one additional child were not included due to a bad video recording. Thirty-eight four-year-olds (3;11–4;11, mean age = 4;0, 23 female) participated in Experiment 1b.

Procedure

Children were tested in the laboratory or in a quiet room in their preschool. They were told that they were going to play a game in which they listened to instructions from the computer and played with toys. Children were seated in front of an inclined podium with four quadrants. At the center of the podium, there was a hole

[1] Note that these item-based frames are quite different from Tomasello's original verb islands (1992). Verb Islands consist of a fixed verb and open slots which can be filled by nominal arguments. In contrast these frames are discontinuous (*It was _____ed by it*) and have an open slot which can be filled by different predicates. This representation presupposes that the predicates appearing in the open slot are implicitly recognized as a part of some larger class of items (e.g., verbs, action words, caused motion predicates). Thus it assumes some level of grammatical abstraction.

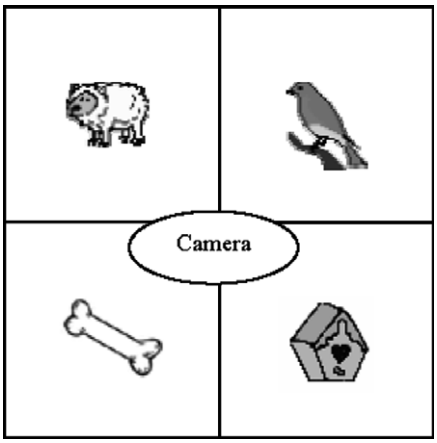

Fig. 1. Example scene as viewed by the participant. The four quadrants each contained a toy. A camera in the center was focused on the participant's face. This set-up was for the trial—double-object: Give the **bird** the dog bone; prepositional-object: Give the **bird** house to the sheep. The ambiguous interval is in bold.

where a camera was placed and focused on the participant's face. The four quadrants of the podium each contained a shelf (see Fig. 1). At the beginning of each trial, the experimenter brought out four toys and placed one on each shelf while labeling the toy at the same time (all critical toys appeared only once. The quadrants targeted by the action were counterbalanced across trials). To ensure that children knew the names of the toys, we asked them on critical trials only to repeat their names and then labeled them again. Next the experimenter asked the child if he/she was ready and then played the sound file. Each trial began with a command to look at the "circle" (where "circle" referred to the hole where the camera was placed). This was intended to bring the child's attention to the podium. A second later, the actual instruction was played. Children were told to listen to the entire instruction before acting it out.

Stimuli

All instructions were pre-recorded by a female native English speaker. To ensure that we retained the children's interest, we limited the study to just four blocks of instructions, which took less than 20 min to complete. Within each block, the first two sentences were filler sentences that were not datives. The third and fourth were prime sentences that were either double-object or prepositional-object datives (e.g., double-object: *Give the lion the ball*; prepositional-object: *Give the ball to the lion*). The fifth and final sentence was the target sentence, also a double-object or prepositional-object dative (e.g., double-object: *Give the bird the dog bone*; prepositional-object: *Give the birdhouse to the sheep*. See Appendix for a complete list). Prime type was crossed with target type such that each child was randomly assigned to one of four possible conditions (double-object prime and double-object target; double-object prime and prepositional-object target; prepositional-object prime and double-object target; prepositional-object prime and prepositional-object target).

In double-object sentences, the first noun is the recipient (usually an animate entity). In prepositional-object sentences the first noun is the theme (usually an inanimate object). On target trials in this experiment, the set of toys that accompanied the utterance contained two items that were phonological matches to the *initial* part of the first noun (e.g. "bird…"). See Fig. 1. One was a possible animate recipient (e.g., bird). The other was a possible inanimate theme (e.g., birdhouse). We were interested in how much the children looked to each of the two items in response to the first noun. From this we could infer which thematic role they had assigned to the initial noun and thus which syntactic frame they were expecting to encounter.

Coding

Eye movements were recorded by the camera centered behind the display and coded following the procedure employed by Snedeker and Trueswell (2004). They found that gaze direction coded from the hidden camera correlated highly with fixations that were simultaneously recorded using head-mounted eye-tracking. Eye movements were coded as being to the center, away or to one of the four quadrants. If the eyes were not visible the frame was coded as track loss and excluded from the analysis. All eye-coding was done with the audio turned off, by coders who were blind to the positions of objects in the visual scene. For 10% of the trials, eye movements were coded by a second coder using the same procedure. Intercoder reliability was 91.2% (Cohen's Kappa = 0.89) for Experiment 1a and 92.8% (Cohen's Kappa = 0.89) for Experiment 1b.

Online-dependent measure

Dependent measures that are commonly used in eye-tracking studies include first gaze duration, latency to first look and total fixation time. Young children's first looks may not be reliably guided by memory for a particular object in a particular location (Fernald, Zangl, Thorpe, Hurtado, & Williams, 2006). Therefore, we did not calculate first gaze duration or latency, and analyzed total fixation time only. We hereafter refer to total fixation time simply as *looks*.

Our analyses focused on the interval during the target trials in which the identity of the direct object, and hence the argument structure of the verb, was temporarily

ambiguous (e.g., *bird*...). Within this interval, we were interested in looks to the potential animate recipient (e.g., bird) and the potential inanimate theme (e.g., birdhouse). We will refer to these two items as *animal* and *object*, respectively. Specifically, we were interested in whether the type of prime sentence influenced how much the children looked to either the animal or the object. We present analyses of three dependent measures:

a. Looks to the animal as a proportion of looks to all four items and the center.
b. Looks to the object as a proportion of looks to all four items and the center.
c. The difference in the proportion of looks to the animal and the object.

Because eye movements are influenced by factors other than the ones manipulated (e.g., visual salience, name frequency, see Henderson & Ferreira, 2004 for discussion), looks to one of the two items (animal or object) may be higher than looks to the other irrespective of the experimental condition. Thus, ceiling or floor effects might lead us to find a significant effect for one of the first two measures but not the other. For example, in pilot studies, we found that adults preferred to look at the animal irrespective of the experimental condition, and we only found significant effects using looks to the *dispreferred* item, namely, the object. Therefore, our primary measure will be looks to the dispreferred item.

We predicted that irrespective of the type of target sentence that they actually hear, children primed with double-object sentences (i.e., sentences where the first noun is the animate recipient) will look relatively more at the animal, while those primed with prepositional-object sentences (i.e., sentences where the first noun is the inanimate theme) will look relatively more at the object. Thus, barring ceiling or floor effects, we expect the following pattern for the three measures listed above,

a. Looks to the animal: double-object prime > prepositional-object prime,
b. Looks to the object: prepositional-object prime > double-object prime,
c. Difference score (animal-object): double-object prime > prepositional-object prime.

Experiment 1a

In this experiment, we asked whether four-year-olds show within-verb priming. Prime sentences used the verb *give* (e.g., double-object: *Give the lion the ball*; prepositional-object: *Give the ball to the lion*). Target sentences also used the verb *give* (e.g., double-object: *Give the bird the dog bone*; prepositional-object: *Give the birdhouse to the sheep*).

Results

We report the results in two sections. The first section describes offline results where we analyze the actions and errors that children performed. The second section describes online results where we analyze children's eye movements to different items over time.

Offline measure: Actions and errors. Children performed the right action on 89% of the target trials (double-object targets = 88%; prepositional-object targets = 90%). For double-object targets, three of the errors were role reversals (e.g., giving the bird *to* the dog bone in response to *Give the bird the dog bone*). One was a failure to perform an action (e.g., picking the two items mentioned but not performing a transfer) and one involved picking a wrong toy. For prepositional-object targets, the errors were as follows: role reversals (3), no action (0) and wrong toy (1). Overall, six out of the nine errors were role reversals. Most (five out of six) were in the mixed conditions, where the prime type did not match the target type, suggesting that children were sometimes led down the wrong path by prime sentences of the opposite type.

Online measure: Eye movements. Fig. 2 shows children's eye movements to items in the visual scene relative to the onset of the first noun ("bird..."). Because we are interested in potential priming effects, we show data for each prime type collapsed across both target types. Data from double-object and prepositional-object prime conditions are always shown in the top and bottom panels, respectively. It takes about 200 ms to program an eye movement (Matin, Shao, & Boff, 1993). Therefore, our critical time interval began 200 ms after the onset of the first noun (e.g., "bird...") and ended 200 ms after the average onset of the subsequent morpheme (e.g., *the* in "Give the bird *the* dog bone"; *house* in "Give the bird*house* to the sheep"). The total interval of interest was 400 ms. In the figures, this is indicated as the analysis window.

Qualitatively, during the analysis window, we see more looks to the animal than the object in the double-object prime conditions (Fig. 2a), and roughly equal looks to both items in the prepositional-object prime conditions (Fig. 2b). For statistical analyses, we computed the average proportion of looks to the animal, proportion of looks to the object, and a difference score for each participant. We excluded those trials where children were looking at the center or away from the display for more than 2/3rd of the interval. This resulted in the elimination of 11% of the trials. Across conditions, children looked at the animal more than the object (difference > 0, $t(19) = 3.336$; $p < .05$). A 2×2 ANOVA

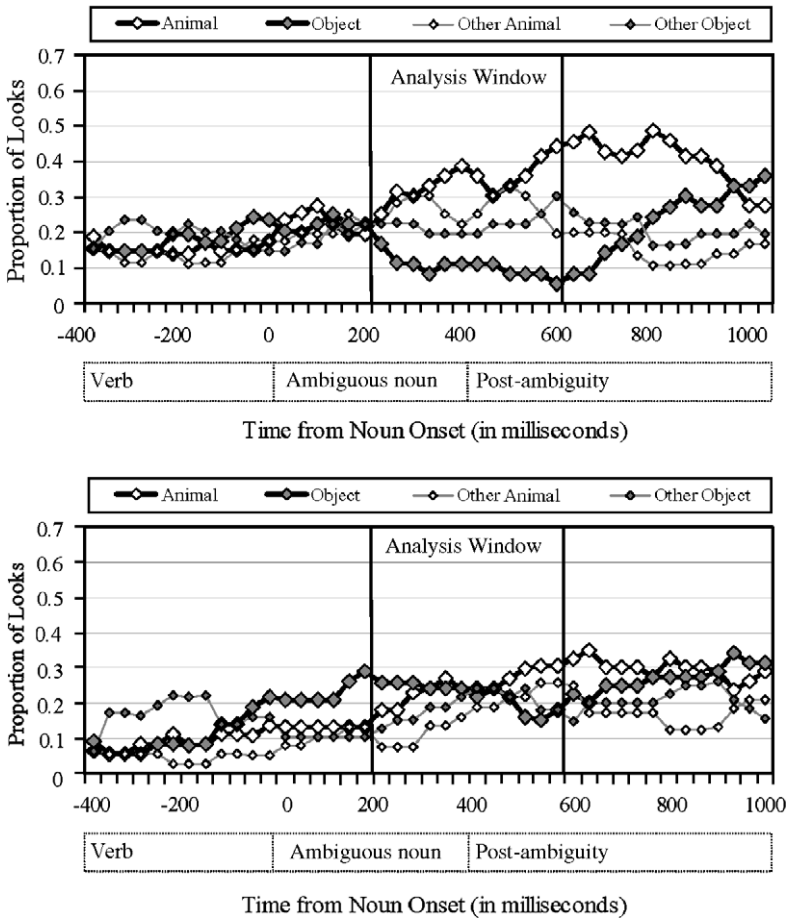

Fig. 2. Proportion of looks to each item type over time (relative to the onset of the first noun). Experiment 1a, four-year-olds, within-verb priming. (a) Double-object prime. (b) Prepositional-object prime.

(Prime Type × Target Type) was conducted for each of the dependent variables with participant as the random variable (Table 1). As predicted, there was a reliable effect of prime type in the analysis of looks to the dispreferred item (the object): participants had more looks to this item in the prepositional-object prime conditions (0.255) than in the double-object prime conditions (0.090). For differences between means, we report 95% confidence intervals (CIs) based on mean squared errors from the participant analyses (Masson & Loftus, 2003). In this experiment, the CI for the 0.165 difference between means was ±0.098. See Fig. 3 for looks in all four experimental conditions. We found a similar effect in the analysis of difference scores: participants in the double-object prime conditions had higher difference scores (0.248) than those in the prepositional-object prime conditions (0.038; CI for the 0.21 difference between means was ±0.148) . In addition, there was a marginal effect of target in this analysis. Those who heard double-object targets showed a higher difference

Table 1
Analysis of variance results for Experiment 1a

Effect	Looks to dispreferred (object)	Looks to preferred (animal)	Difference score
Prime	$F(1,16) = 12.828^{**}$	$F(1,16) = 0.471$	$F(1,16) = 9.013^{**}$
Target	$F(1,16) = 2.259$	$F(1,16) = 0.806$	$F(1,16) = 3.354^{\dagger}$
Prime * Target	$F(1,16) = 0.108$	$F(1,16) = 0.294$	$F(1,16) = 0.085$

Note. $^{\dagger}p < .1$; $^{**}p < .01$.

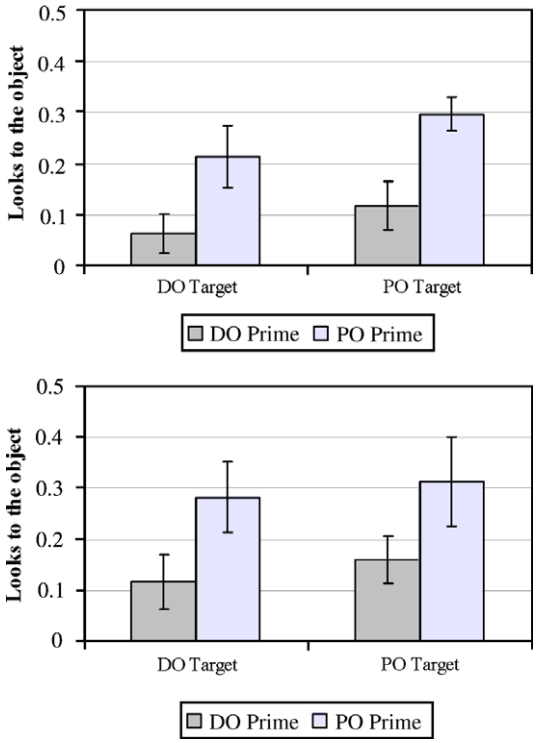

Fig. 3. Mean proportion of looks to the dispreferred item (object) in the analysis window. All four experimental conditions are shown. Four-year-olds. (a) Within-verb priming. (b) Across-verb priming.

score than those who heard prepositional-object targets. This may have been due to subtle acoustic differences between double-object and prepositional-object targets during the ambiguous interval. There were no reliable effects in the analysis of looks to the preferred item (the animal).

Summary of Experiment 1a

We found that four-year-old children's interpretation of temporarily ambiguous *give* sentences was influenced by the previous *give* sentences that they heard. Those children primed with prepositional-object sentences (where the first noun is the inanimate theme) looked relatively more at the object than those primed with double-object sentences (where the first noun is the animate recipient). This priming effect unfolds soon after the children begin to hear the first noun.

Experiment 1b

In Experiment 1a, we used the same verb in both prime and target sentences. This within-verb priming could result from either verb-specific or abstract representations. To explore whether four-year-olds have representations that are broader than individual verbs, we looked for across-verb priming in Experiment 1b. Prime dative sentences used *show* and *bring* (e.g., double-object: *Show the lion the ball*; prepositional-object: *Show the ball to the lion*). Target dative sentences used *give* just as in Experiment 1a (e.g., double-object: *Give the bird the dog bone*; prepositional-object: *Give the birdhouse to the sheep*).

Results

Offline measure: Actions and errors. Children performed the correct action on 90% of the target trials (double-object targets = 94%; prepositional-object targets = 85%). For double-object targets, the errors were: role reversal (3), no action (1) and wrong toy (1). For prepositional-object targets, they were: role reversal (3), no action (5) and wrong toy (3). Overall, six out of the 16 errors were role reversals. Most were in the mixed conditions (five out of six), where the prime type was different from the target type.

Online measure: Eye movements. Fig. 4 shows the eye movements of children in the double-object prime (4a) and prepositional-object prime (4b) conditions. Qualitatively, during the analysis window, we see more looks to the animal than the object in the double-object prime conditions, and roughly equal looks to both items in the prepositional-object prime conditions. We computed average-dependent measures for each participant. Twelve percent of the trials were excluded because the child looked away from the four items for more than 2/3rd of the interval. As in Experiment 1a, children showed an overall preference for the animal over the object [$t(36) = 2.132$; $p < .05$]. A 2×2 participants ANOVA (Prime Type × Target Type) was conducted for each of the dependent variables (Table 2). As predicted, looks to the dispreferred item (the object) were higher in the prepositional-object prime conditions (0.297) than in the double-object prime conditions (0.139; CI for the 0.158 difference between means was ±0.135). See Fig. 3 for looks in all four experimental conditions. Difference scores were somewhat higher in the double-object prime conditions (0.255) than in the prepositional-object prime conditions (0.035), but this effect did not reach significance ($p = .11$; CI for the 0.22 difference between means was ±0.273). As before, there were no reliable effects in the analysis of looks to the preferred item (the animal).

Summary of Experiment 1b

In Experiment 1b, we found that four-year-old children's interpretation of temporarily ambiguous *give* sentences was influenced by the previous *show* or *bring* sentences that they heard. Those children primed with prepositional-object sentences (where the first noun is the inanimate theme) looked relatively more at the object than those primed with double-object sentences (where the first noun is the animate recipient). This

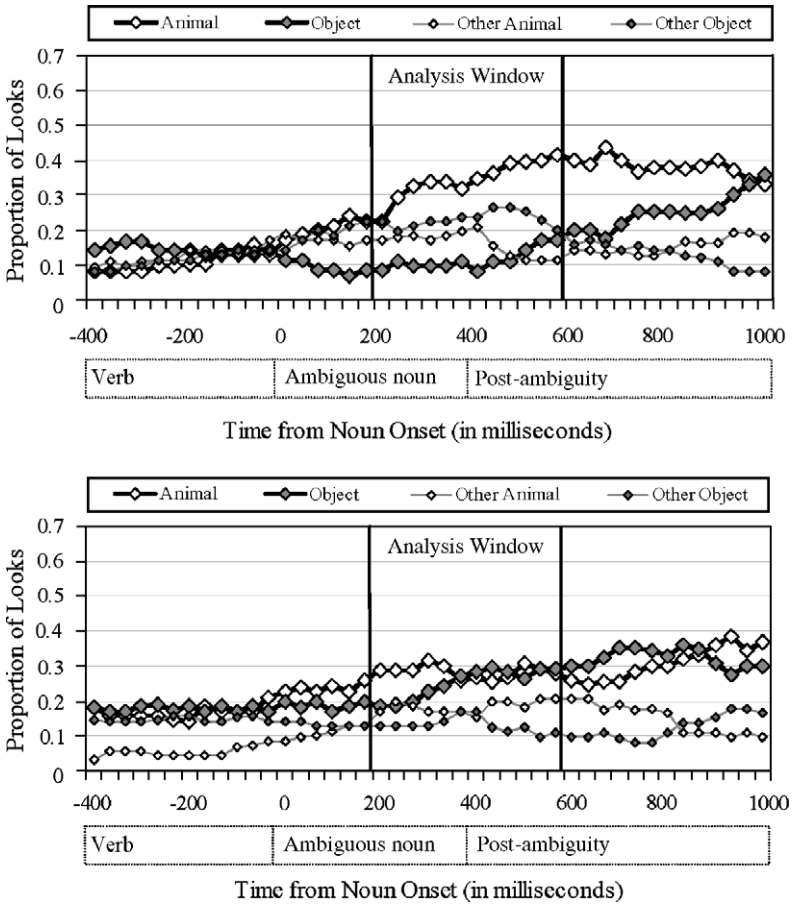

Fig. 4. Proportion of looks to each item type over time (relative to the onset of the first noun). Experiment 1b, four-year-olds, across-verb priming. (a) Double-object prime. (b) Prepositional-object prime.

Table 2
Analysis of variance results for Experiment 1b

Effect	Looks to dispreferred (object)	Looks to preferred (animal)	Difference score
Prime	$F(1,33) = 5.623^*$	$F(1,33) = 0.562$	$F(1,33) = 2.677$
Target	$F(1,33) = 0.313$	$F(1,33) = 1.597$	$F(1,33) = 0.247$
Prime * Target	$F(1,33) = 0.01$	$F(1,33) = 0.915$	$F(1,33) = 0.404$

Note. $^*p < .05$.

priming across verbs suggests that four-year-olds have abstract structural representations of dative utterances.

Experiment 2

Experiment 1 demonstrated within- and across-verb priming in four-year-old children. However, much of the debate about the abstractness of children's representations has centered on three-year-olds. In addition, all target sentences in Experiment 1 used *give*. The verb *give* is likely the most frequent dative verb in the input given to children. Under some theories, *give* conveys the prototypical meaning or central sense of the double-object construction (Goldberg, 1995). It has also been suggested that *give* has a privileged role in the acquisition of dative constructions and serves as a "path-breaking" verb (Ninio, 1999; cf. Campbell & Tomasello, 2001). Therefore in Experiment 2, we extended our paradigm to younger children (three-year-olds), and to a wider variety of dative verbs (enabling us to do both participants- and items-analyses). Again we looked for both within-verb priming (Experiment 2a) and across-verb priming (Experiment 2b).

Participants

Thirty young three-year-olds (2;11–3;4, mean age = 3;1, 16 female) participated in Experiment 2a. Two other children were tested but not included: one due to a failure to comply with the experimental procedure, and the other because the session was interrupted. Thirty-two young three-year-olds (2;11–3;4, mean age = 3;1, 14 female) participated in Experiment 2b. One additional child was excluded due to a failure to comply.

Procedure

The testing procedure was the same as in Experiment 1.

Stimuli

Children were randomly assigned to one of two groups. The first group heard *pass, send, throw* and *bring* as target verbs. The second group heard *hand, show, toss* and *take* as target verbs. Thus, with the two groups combined, we tested for priming with eight different dative verbs, none of which were *give*. An additional change from Experiment 1 was that we did not use compound nouns such as *birdhouse* in target sentences (because we were unsure whether three-year-olds would know them). Instead we used animal/object name pairs that overlapped at the onset (e.g., double-object: *Show the* ***horse*** *the book*; prepositional-object: *Show the* ***horn*** *to the dog*). See Appendix for a list of the target dative sentences.

Coding

The coding procedure was the same as in Experiment 1. Intercoder reliability for the coding of eye movements was 91.6% (Cohen's Kappa = 0.90) for Experiment 2a and 91.3% (Cohen's Kappa = 0.90) for Experiment 2b.

Online-dependent measure

We used the same three measures as in Experiment 1. However, we used longer time windows for the analyses because the three-year-olds were slower and more variable in their eye movements than the four-year-olds. Estimates of saccade latencies for different ages and different tasks are not yet known. While minimum saccade latencies can be as small as 133 ms for adults in a simple visual task, the latencies for young children in a task where all stimuli stay visible throughout the trial and there is phonological overlap amongst the visible items is likely to be higher. For example, Swingley, Pinto, and Fernald (1999) found mean latencies of 558 and 785 ms for adults and 24-month-olds, respectively. In our experiments, average latencies to look at the first mentioned item on 10 randomly selected, unambiguous prime trials were as follows: three-year-olds (M = 983 ms, SD = 292 ms) and four-year-olds (M = 437 ms, SD = 188 ms). Because the relevant time window for capturing the three-year-olds' responses to the first noun is unclear, we present analyses for two different time windows:

a. A coarse temporal window that covers the entire duration from the onset of the first noun to the end of the sentence, with a 200-ms offset (200–2200 ms after noun-onset). Using this broad window for our primary analyses maximizes our chances of capturing a priming effect (if one exists) without increasing the probability of a false positive by conducting tests over multiple time windows.
b. A finer temporal window that covers all latencies within one standard deviation of the mean latency recorded above (600–1300 ms after noun-onset). By conducting a secondary analysis that is linked more tightly to the ambiguous noun, we may increase our signal-to-noise ratio and gain information about the time course of the priming effect.

These longer time windows may include looks that were programmed after the first noun was disambiguated. Therefore, we might expect to see an effect of target type in addition to any priming effects.

Experiment 2a

We first asked whether three-year-olds show within-verb priming. Each child heard one of two lists, each containing four different dative verbs, but within a given block, the prime and the target verbs were the same.

Results

Offline measure: Actions and errors. Children performed the right action on 79% of the target trials (double-object targets = 66%; prepositional-object targets = 95%). For double-object targets, the errors were: role reversals (1), no action (18) and wrong toy (3). For prepositional-object targets, the errors were: role reversals (0), no action (1) and wrong toy (2). Thus, role reversals constituted only a minority of errors (1 out of 25). Most of the errors were due to children not acting out double-object sentences. On these trials the children typically picked up both the toys mentioned but did not carry out the action. We consider possible reasons for this difficulty in the General discussion section.

Online measure: Eye movements. Eye movements for double-object and prepositional-object prime conditions are shown in Fig. 5a and b, respectively. Qualitatively, we see roughly equal looks to the animal and the object in the double-object prime conditions, and substantially more looks to the object in the prepositional-object prime conditions. We present the analyses for the coarse temporal window first. Average-dependent measures were computed for each participant and each item (verb). Nine percent of the trials were excluded due to track loss or a failure to look at any of the stimulus items. Across conditions, children showed a marginal preference for the object over the animal [$t(29) = 1.96$; $p = .06$]. ANOVAs were conducted for each of the dependent variables with Prime Type and Target Type as between participants and within item variables (Table 3). As predicted, looks to the dispreferred item (the animal) were higher in the double-object prime conditions (0.314) than in the prepositional-object prime conditions (0.202; CI for the 0.112 difference between means was ±0.088). See Fig. 6 for looks in all four experimental conditions. The effect of Prime Type was also present in the analysis of the difference scores: these scores were higher in the double-object prime conditions (−0.031) than in the prepositional-object prime conditions (−0.207; CI for the 0.176 difference between means was ±0.173). Unsurprisingly, there was also a significant effect of Target Type for all three dependent measures. Participants looked more at the animal for double-object targets than for prepositional-object targets, and more at the object for prepositional-object targets than for double-object targets. Finally, there was an interaction between prime and target in the analysis of looks to the animal, which was significant only in the participants analysis. The priming effect was stronger for double-object target sentences (double-object prime = 0.429; prepositional-object prime = 0.227) than for prepositional-object target sentences (double-object prime = 0.198; prepositional-object prime = 0.177). Results for the finer temporal window show a similar pattern (Table 4). The critical effect persisted in these analyses: looks to the dispreferred item (the animal)

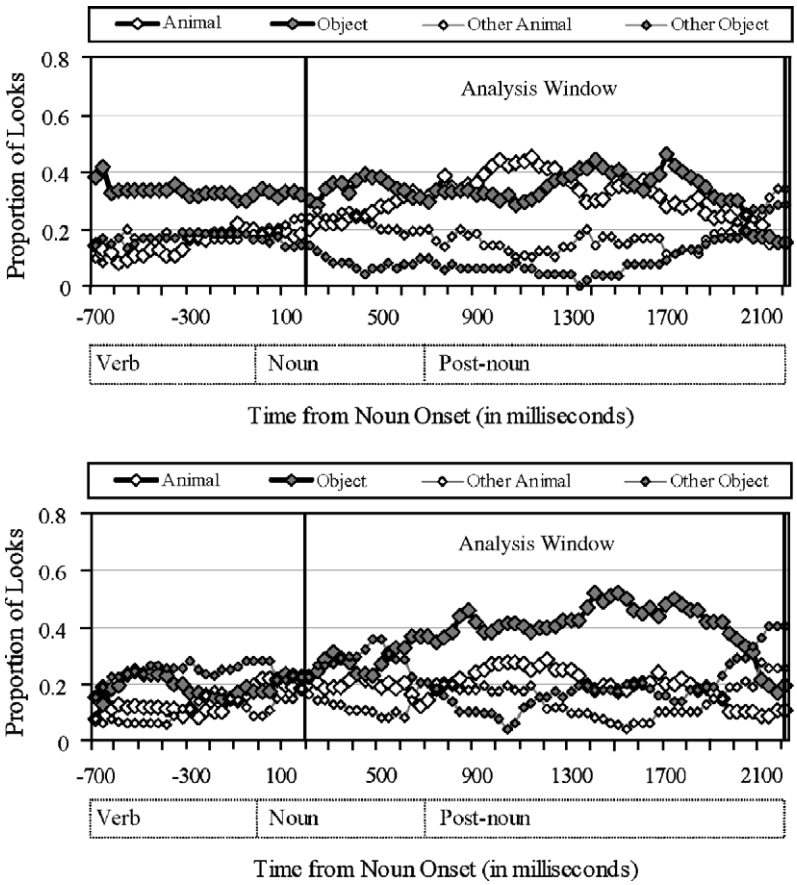

Fig. 5. Proportion of looks to each item type over time (relative to the onset of the first noun). Experiment 2a, three-year-olds, within-verb priming. (a) Double-object prime. (b) Prepositional-object prime.

Table 3
Analysis of variance results for Experiment 2a: Coarse temporal window

Effect	Looks to dispreferred (animal)	Looks to preferred (object)	Difference score
Prime	$F1(1,26) = 6.714^{*}$ $F2(1,7) = 7.911^{*}$ $\min F'(1,24) = 3.631^{\dagger}$	$F1(1,26) = 1.319$ $F2(1,7) = 1.646$ $\min F'(1,25) = 0.732$	$F1(1,26) = 4.356^{*}$ $F2(1,7) = 8.184^{*}$ $\min F'(1,30) = 2.843$
Target	$F1(1,26) = 10.65^{**}$ $F2(1,7) = 9.675^{*}$ $\min F'(1,21) = 5.069^{*}$	$F1(1,26) = 14.473^{**}$ $F2(1,7) = 6.723^{*}$ $\min F'(1,14) = 4.59^{\dagger}$	$F1(1,26) = 17.542^{**}$ $F2(1,7) = 9.534^{*}$ $\min F'(1,15) = 6.177^{*}$
Prime * Target	$F1(1,26) = 4.408^{*}$ $F2(1,7) = 2.938$ $\min F'(1,17) = 1.763$	$F1(1,26) = 0.003$ $F2(1,7) = 0.049$ $\min F'(1,29) = 0.003$	$F1(1,26) = 1.231$ $F2(1,7) = 1.448$ $\min F'(1,24) = 0.665$

Note. $^{\dagger}p < .1$; $^{*}p < .05$; $^{**}p < .01$.

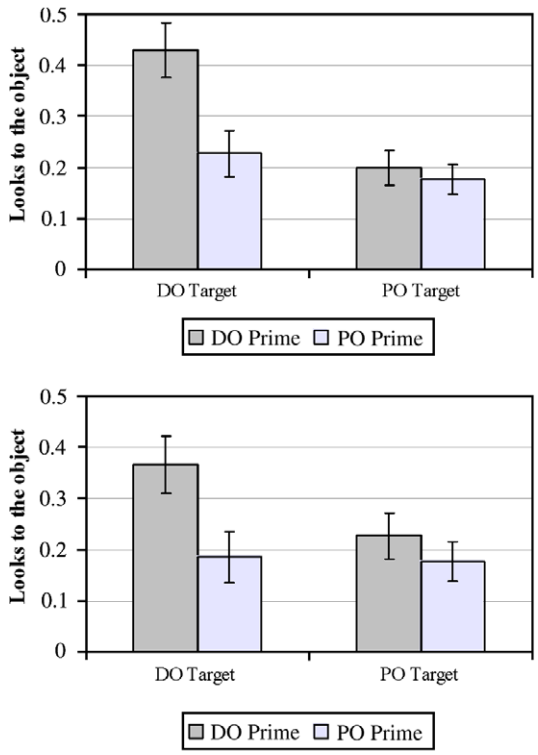

Fig. 6. Mean proportion of looks to the dispreferred item (animal) in the coarse temporal window. All four experimental conditions are shown. Three-year-olds. (a) Within-verb priming. (b) Across-verb priming.

were higher in the double-object prime conditions (0.376) than in the prepositional-object prime conditions (0.225; CI for the 0.151 difference between means was ±0.144).

The error rate amongst three-year-olds was considerably higher than amongst four-year-olds. Because eye movements on error trials are hard to interpret, we performed secondary analyses excluding those trials where children committed errors. An ANOVA of looks to the dispreferred item (the animal) during the coarse temporal window showed an effect of prime significant by participants only [$F1(1,26) = 4.781$, $p < .04$; $F2(1,6) = 2.461$, $p > .1$; $\min F'(1,13) = 1.625$, $p > .1$]. There was also an effect of target [$F1(1,26) = 9.773$, $p < .01$; $F2(1,6) = 8.656$, $p < .03$; $\min F'(1,18) = 4.590$, $p < .05$], and an interaction marginally significant by participants only [$F1(1,26) = 3.978$, $p < .1$; $F2(1,6) = 1.159$, $p > .1$; $\min F'(1,10) = 0.897$, $p > .1$]. Thus, the overall pattern of results was similar to the analyses that included all trials.

Summary of Experiment 2a

In Experiment 2a, we found within-verb priming in three-year-old children using eight different dative verbs. Those primed with double-object sentences looked relatively more at the animal than those primed with prepositional-object sentences. These results demonstrate that priming is not restricted to frequent, prototypical dative verbs such as *give*.

Experiment 2b

While the within-verb priming found in Experiment 2a could arise from either verb-specific or more abstract representations, across-verb priming can only result from more abstract representations. Accordingly, in this experiment, we explored whether three-year-olds show across-verb priming. The target sentences were the same as in Experiment 2a (one group of children heard *pass, send, throw* and *bring* as target verbs; another heard *hand, show, toss* and *take* as target verbs). The prime sentences used the target verbs from the other group. Thus, unlike Experiment 2a, the prime and the target verbs were different within each block. In addition, the two prime sentences in each block used two different verbs because varied primes have been found to lead to greater priming in older children (Savage et al., 2006).

Table 4
Analysis of variance results for Experiment 2a: Fine temporal window

Effect	Looks to dispreferred (animal)	Looks to preferred (object)	Difference score
Prime	$F1(1,26) = 4.589^{*}$ $F2(1,7) = 5.631^{*}$ $\min F'(1,25) = 2.528$	$F1(1,26) = 0.477$ $F2(1,7) = 0.725$ $\min F'(1,27) = 0.287$	$F1(1,26) = 2.372$ $F2(1,7) = 5.590^{\dagger}$ $\min F'(1,32) = 1.665$
Target	$F1(1,26) = 12.342^{**}$ $F2(1,7) = 8.076^{*}$ $\min F'(1,17) = 4.881^{*}$	$F1(1,26) = 8.267^{**}$ $F2(1,7) = 9.563^{*}$ $\min F'(1,24) = 4.434^{*}$	$F1(1,26) = 13.481^{**}$ $F2(1,7) = 9.371^{*}$ $\min F'(1,18) = 5.528^{*}$
Prime * Target	$F1(1,26) = 0.961$ $F2(1,7) = 2.088$ $\min F'(1,31) = 0.658$	$F1(1,26) = 0.081$ $F2(1,7) = 0.220$ $\min F'(1,32) = 0.059$	$F1(1,26) = 0.468$ $F2(1,7) = 1.153$ $\min F'(1,32) = 0.333$

Note. $^{\dagger}p < .1$; $^{*}p < .05$; $^{**}p < .01$.

Results

Offline measure: Actions and errors. Children performed the right action on 75% of the target trials (double-object targets = 63%; prepositional-object targets = 88%). For double-object targets, the errors were: role reversal (13), no action (5) and wrong toy (6). For prepositional-object targets, the errors were: role reversal (2), no action (3) and wrong toy (3). Overall, 15 of the 32 errors were role reversals. These were not higher in the mixed conditions ($N = 6$) compared to the unmixed conditions ($N = 9$). Instead, most of the reversal errors were due to four children in the double-object prime and double-object target condition who acted out many prime and target sentences as if they were prepositional-object sentences (see General discussion).

Online measure: Eye movements. Fig. 7 shows eye movements in the double-object prime (7a) and prepositional-object prime (7b) conditions. In both graphs, we see a high proportion of looks to the object. However, in the double-object prime conditions, there are roughly equal looks to the animal, while in the prepositional-object prime conditions there are relatively fewer looks to the animal. We computed average-dependent measures for each participant and each item (verb). Again, we present results for the coarse temporal window first. Six percent of the trials were eliminated due to track loss or failure to look at the four toys for the entirety of the interval. Across conditions, children showed a preference for the object over the animal [$t(31) = 2.295$; $p < .05$]. For each of the dependent variables ANOVAs were conducted with Prime Type and Target Type as between participants and within item variables (Table 5). As predicted, looks to the dispreferred item (the animal) were higher in the double-object prime conditions (0.297) than in the prepositional-object prime conditions (0.182; CI for the 0.115 difference between means was ±0.097) resulting in a reliable effect of Prime Type. See Fig. 6 for looks in all four experimental conditions. The effect of prime was also reliable for the difference scores which were higher in the double-object prime conditions (−0.017) than in the prepositional-object prime conditions (−0.163; CI for the 0.146 difference between means was ±0.134). Finally there was an effect of target on looks to the preferred item (the object) and on the difference scores. Those who heard prepositional-object targets looked more at the object than those who heard double-object targets. Results for the finer temporal window show a similar pattern (Table 6). As predicted, looks to the dispreferred item (the animal) were higher in the double-object prime conditions (0.318) than in the prepositional-object prime conditions (0.187; CI for the 0.131 difference between means was ±0.134). However, this effect just failed to reach conventional levels of significance in both the participant and item analyses.

As in Experiment 2a, we performed secondary analyses excluding those trials where children committed errors. An ANOVA of looks to the dispreferred item (the animal) during the coarse temporal window showed an effect of prime significant by items and marginally significant by participants [$F1(1,28) = 4.093$, $p = .053$; $F2(1,6) = 10.434$, $p < .02$; $\min F'(1,32) = 2.939$, $p = .096$]. There were no other effects. Thus, the overall pattern of results resembles the analyses that included all trials.

Summary of Experiment 2b

The results from Experiment 2b show that three-year-olds' interpretation of target dative sentences was influenced by the previous dative sentences that they heard, even when the prime and target sentences used different verbs. Children primed with double-object sentences looked relatively more at the animal than children primed with prepositional-object sentences. This priming across verbs suggests that three-year-olds have some abstract representations that are not specific to individual verbs. These abstract representations may be verb-general syntactic structures, or mappings between semantic or animacy features and syntactic slots (see General discussion).

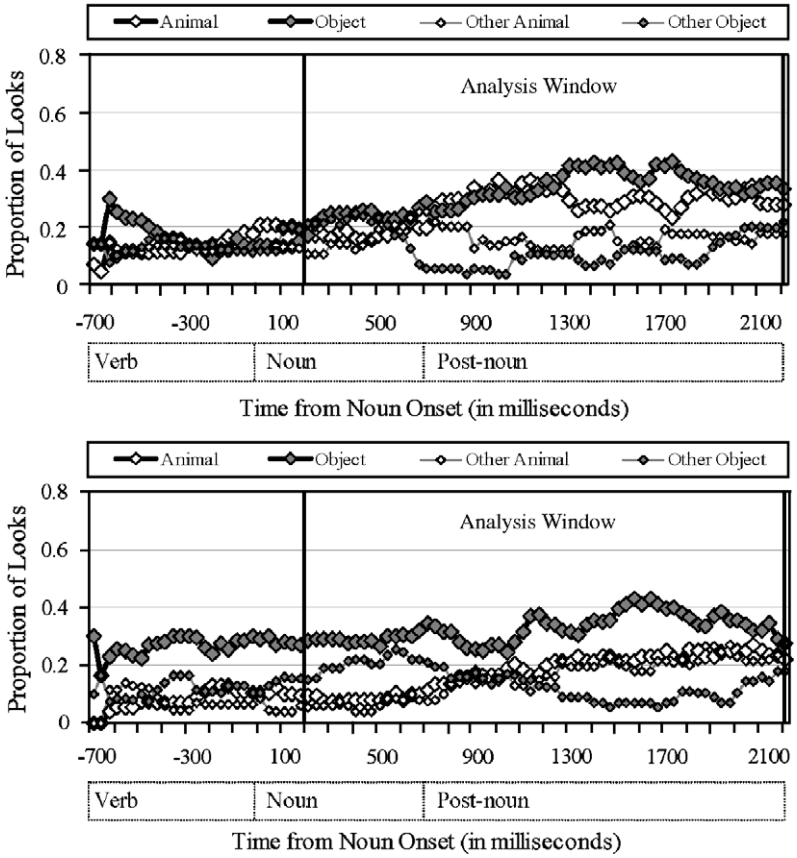

Fig. 7. Proportion of looks to each item type over time (relative to the onset of the first noun). Experiment 2b, three-year-olds, across-verb priming. (a) Double-object prime. (b) Prepositional-object prime.

Table 5
Analysis of variance results for Experiment 2b: Coarse temporal window

Effect	Looks to dispreferred (animal)	Looks to preferred (object)	Difference score
Prime	$F1(1,28) = 5.740^{*}$ $F2(1,7) = 8.517^{*}$ $\min F'(1,28) = 3.437^{\dagger}$	$F1(1,\ 28) = 0.572$ $F2(1,7) = 0.875$ $\min F'(1,28) = 0.346$	$F1(1,\ 28) = 4.959^{*}$ $F2(1,7) = 5.518^{\dagger}$ $\min F'(1,24) = 2.612$
Target	$F1(1,\ 28) = 2.364$ $F2(1,7) = 1.612$ $\min F'(1,18) = 0.958$	$F1(1,\ 28) = 7.148^{*}$ $F2(1,7) = 5.811^{*}$ $\min F'(1,20) = 3.205^{\dagger}$	$F1(1,\ 28) = 7.980^{**}$ $F2(1,7) = 7.800^{*}$ $\min F'(1,22) = 3.944^{\dagger}$
Prime * Target	$F1(1,\ 28) = 1.861$ $F2(1,7) = 3.684^{\dagger}$ $\min F'(1,31) = 1.236$	$F1(1,\ 28) = 1.35$ $F2(1,7) = 1.004$ $\min F'(1,19) = 0.576$	$F1(1,\ 28) = 3.008^{\dagger}$ $F2(1,7) = 2.501$ $\min F'(1,20) = 1.365$

Note. $^{\dagger}p < .1$; $^{*}p < .05$; $^{**}p < .01$.

Comparison of three- and four-year-olds

Behaviorally, the three-year-olds in Experiment 2 differed from the four-year-olds in Experiment 1 in two notable ways: (a) three-year-old children performed more errors in acting out double-object sentences, and (b) the priming effect in three-year-olds was sometimes stronger for double-object target sentences than for prepositional-object target sentences (e.g., Table 3). There are several possible reasons for these differences. First, different verbs were used for the two age groups; for the four-year-olds all the target sentences contained

Table 6
Analysis of variance results for Experiment 2b: Fine temporal window

Effect	Looks to dispreferred (animal)	Looks to preferred (object)	Difference score
Prime	$F1(1,27)=4.058^{\dagger}$ $F2(1,7)=5.508^{\dagger}$ $\min F'(1,26)=2.336$	$F1(1,\ 27)=.780$ $F2(1,7)=1.948$ $\min F'(1,33)=0.557$	$F1(1,27)=3.079^{\dagger}$ $F2(1,7)=4.287^{\dagger}$ $\min F'(1,27)=1.792$
Target	$F1(1,\ 27)=0.515$ $F2(1,7)=0.147$ $\min F'(1,11)=0.114$	$F1(1,\ 27)=0.012$ $F2(1,7)=0.2$ $\min F'(1,30)=0.011$	$F1(1,\ 27)=0.25$ $F2(1,7)=0.319$ $\min F'(1,25)=0.140$
Prime * Target	$F1(1,\ 27)=0.843$ $F2(1,7)=0.601$ $\min F'(1,18)=0.351$	$F1(1,\ 27)=1.112$ $F2(1,7)=0.352$ $\min F'(1,12)=0.267$	$F1(1,\ 27)=1.439$ $F2(1,7)=0.623$ $\min F'(1,14)=0.435$

Note: $^{\dagger}p<.1$.

give, while the three-year-olds heard sentences with eight different target verbs. To explore the differences between these verbs, we examined Gries and Stefanowitsch's (2004) estimates of the probability of each verb appearing in double-object structures relative to its probability of appearing in prepositional-object structures. These estimates are based on the British component of the International Corpus of English (ICE-GB) which consists of a million words of spoken and written English (information about the bias of these verbs in child-directed speech was not available). We found that *give*, the target verb for the four-year-olds, is double-object-biased, appearing more often in double-object sentences than in prepositional-object sentences. In contrast, a majority of the target verbs used with the three-year-olds are prepositional-object-biased. Prior prepositional-object-bias may have caused three-year-olds some difficulty with double-object sentences. In addition this bias could explain why the priming effect is weaker for prepositional-object targets. In the prepositional-object target conditions, verb-bias leads the listener towards the (correct) prepositional-object interpretation *and* this interpretation is further strengthened by prosodic information about the identity of the ambiguous noun. This collusion of cues may be so potent that it may have masked any effect of the priming manipulation.

Second, three-year-olds may have had difficulty with the double-object sentences because of phonological and discourse constraints that shape the use of the double-object construction. In the present experiment both the recipient and theme were described with short definite noun phrases that referred to entities that had been previously introduced but were not highly accessible. Under these conditions both prepositional-object and double-object utterances are possible and both four-year-olds and adults have little difficulty interpreting them (see Thothathiri & Snedeker, 2006). However, in natural discourse the double-object construction appears to be more limited in its use. The vast majority of double-object utterances occur in contexts in which the recipient is given information and encoded with a pronoun, while the theme is new information and thus encoded with a full noun phrase (Collins, 1995). This pattern may be even more pronounced in child-directed speech with its restricted contexts and heavy use of pronouns. Perhaps some of the three-year olds were reluctant to settle on the double-object interpretation in our experiments because the phonological form and discourse context did not match these probabilistic constraints. Critically for our purposes however, the three-year-olds performed correct actions on at least 75% of the target trials, and we found significant priming effects even when we excluded the error trials.

Several factors limit our ability to directly compare the findings for the three- and four-year-olds. The two studies used different props, different sentences and different verbs. There were also two differences in our analyses. First, our primary measure was looks to the object for the four-year-olds and looks to the animal for the three-year-olds. This choice of dependent measure was a principled one: in each case it was based on the overall looking preferences for that particular age group. Furthermore, in both cases the measure that we selected on the basis of the data from the within-verb study was applied—successfully—in our analysis for the between-verb study, confirming our original selection criterion. Second, the length of the analysis window was different for the two age groups. A longer window was used for the three-year-olds because they had a longer latency to look at mentioned objects during the prime trials. This longer window often resulted in target effects in addition to the prime effects. While this difference may limit our interpretation of the age differences, it in no way takes away from our central finding. In the critical across-verb priming experiment with three-year-olds, we found robust effects of prime type on looks to the dispreferred item in the absence of any effect of target (Table 5). In the analysis of the finer temporal

window marginal priming effects persisted in the absence of any target effects (Table 6).

Overall, because the stimuli and the analyses were different for the two age groups, we interpret the results cautiously. We take them as showing across-verb priming in both three- and four-year-old children but draw no strong conclusions about the relative strength of the priming effects (see General discussion).

Comparing within-verb and across-verb priming

While structural priming occurs even when two utterances share no content words, some researchers have found that priming in adults is greater when the same verb is used in both sentences (Pickering & Branigan, 1998). Similarly, in a study with children, Branigan, McLean, and Jones (2005) found enhanced priming of noun phrases when the head noun was repeated. Pickering and Branigan explain the verb-priming results with a theory in which individual verbs are linked to abstract combinatorial representations such as [Noun Phrase, Noun Phrase] and [Noun Phrase, Prepositional Phrase]. These abstract combinatorial nodes are shared between verbs, leading to across-verb priming. In addition, the link between an individual verb and a combinatorial node can be potentiated, leading to an advantage for within-verb priming.

To explore whether our results accord with this pattern, we compared within- and across-verb priming for both groups of children. For three-year-olds, the effect sizes for within- and across-verb priming were 0.205 and 0.170, respectively (partial η^2 for looks to the dispreferred item [the animal]). For four-year-olds, the within-verb and across-verb priming effect sizes were 0.445 and 0.146, respectively (partial eta-squared for looks to the dispreferred item [the object]). Thus, for both three- and four-year-olds, within-verb priming appears to be stronger than across-verb priming. However, the interaction between prime type and experiment was not significant for either group [within- and across-verb differences between prime conditions are summarized in Table 7; Fs < 1, ps $> .1$]. Lack of statistical power may be one reason for the null effect. Alternatively, a recent study suggested that the advantage for within-verb priming is strongest when there is a relatively short lag between prime and target sentences (Konopka & Bock, 2005). The interactive act-out task that we employed involved long lags between prime and target trials (conversation lasting between half to one minute). This may have decreased our chances for finding significant lexical enhancement of priming. Further studies of the effect of lag on priming can elucidate how lexical and abstract representations interact during online processing in children.

Table 7
Comparison of within- and across-verb priming effects

Age group	Difference between prime conditions	
	Within-verb	Across-verb
Three-year-olds	0.112 (CI = ±0.088)	0.115 (CI = ±0.097)
Four-year-olds	0.165 (CI = ±0.098)	0.158 (CI = ±0.135)

Absolute value of the difference between prime conditions in mean looks to the dispreferred item.

General discussion

The results reported here demonstrate within- and across-verb priming in both three- and four-year-old children. Prior dative sentences influenced the online comprehension of subsequent dative sentences containing either the same or a different verb. The across-verb priming results can only be explained by representations that are not verb-specific. Therefore, these results suggest that both three- and four-year-old children use abstract representations during comprehension.

Possible representations underlying the priming effect

What is the source of the priming effect? Our methodology rules out an alternate explanation for previous production-priming results found in children. Because the alternate constructions used in those priming studies are distinguished by the presence or absence of closed-class words (e.g., *to*), production effects could reflect the priming of these words rather than grammatical structures. We avoided this possibility by measuring priming of the interpretation of the direct object noun, which *precedes* this critical morpheme. This is clearest for the four-year-olds where our entire time window of analysis preceded the onset of "to" (with a 200-ms offset). However, even for the three-year-olds, differences between the double-object and prepositional-object prime conditions begin to emerge prior to the onset of this morpheme (Figs. 5 and 7).

Thus, these results clearly demonstrate that children's language comprehension relies on generalizations that extend beyond individual lexical items. There are however, several possible representations that could underlie these priming effects. The first class of explanations, and the least interesting, involves the priming of structures that include no representation of the phrase structure of the utterance or the argument structure of the verb. Perhaps children in the double-object prime conditions formed the expectation that they would hear "syllable syllable animate" or they learned a rule such as "animal will be mentioned first". Similarly, children in the prepositional-object prime conditions may have been primed for "syllable syllable inanimate" or "object will be mentioned first". To explore these explanations, in

Experiment 2a, we changed the first filler sentence in each block to contain a temporary phonological ambiguity (e.g., *Hold the bunny up over your head*. See Table 8). The visual scene for these fillers contained an animal/object pair with labels that had overlapping onsets (e.g., *bunny*/*bun*). As mentioned earlier, each block of instructions consisted of two fillers, two prime dative sentences and one target dative sentence, in that order. Thus, we can look at whether the dative sentences in one block influenced the interpretation of the first filler sentence in the next block. Because the critical filler in the *first* block was not preceded by dative sentences that could potentially prime for animacy, we added two transitive sentences before this filler. These sentences had direct objects that matched the direct objects in dative target sentences in animacy. We only consider the "unmixed" conditions i.e., conditions in which the prime and target sentences were of the same type. Note that this results in three "primes" for the fillers in blocks 2–4, thereby serving as a strong test of the "animal or object first hypothesis". See Table 8 for the complete design. If children were merely expecting that an animal or object was going to be mentioned first, we would expect that children who have just heard a sentence where the first noun is animate (e.g., *Show the tiger the letter, Turn the rhino upside down*) would look more at the animal (e.g., *bunny*), while those who have just heard a sentence where the first noun is inanimate (e.g., *Show the letter to the tiger, Turn the cup upside down*) would look more at the object (e.g., *bun*). We performed an analysis of looks to the animal in the coarse temporal window just as we did for the main analysis in Experiment 2a. As before, we excluded those trials where children were not looking at any of the items. ANOVA results are shown in Table 9. We found a strong effect of target type but also a marginal effect of prime type. Looks to the animal were greater in the double-object prime conditions (0.462) than in the prepositional-object prime conditions (0.311; CI for the 0.151 difference between means was ±0.157). To isolate the effect of the transitive primes for the first block, we analyzed block 1 and blocks 2–4 separately. As seen in Table 9, the prime effect appears to be driven by the first block in which transitive primes were used. For the first block alone, looks to the animal were greater in the double-object prime conditions (0.789) than in the prepositional-object prime conditions (0.532; CI for the 0.257 difference between means was ±0.202). In contrast, the difference between double-object prime (0.417) and prepositional-object prime (0.331; CI for the 0.086 difference between means was ±0.28) conditions was much smaller and statistically insignificant for blocks 2–4.

Thus, we find that the animacy of the direct object *can* be primed, at least for transitive verbs with unambiguous post-verbal argument structures, but this priming is restricted. Any account of these findings must explain why datives prime datives; transitives prime transitives; but datives do not prime transitives. One possibility is that transitive-to-transitive animacy priming is dependent on conceptual or semantic overlap (rather than syntactic similarity). Perhaps the transitive primes led participants to develop expectations about

Table 8
Temporarily ambiguous fillers in Experiment 2a

Block	Prime	Target
1	Two transitive primes (e.g., Turn the rhino/cup upside down)	Animate noun: Hold the bunny up over your head (distractor: bun)
2	Three dative primes (e.g., Send the frog the gift/Send the gift to the frog)	Inanimate noun: Touch the light very carefully (distractor: lion)
3	Three dative primes (e.g., Toss the zebra the towel/Toss the towel to the zebra)	Inanimate noun: Squeeze the pillow with both hands (distractor: pig)
4	Three dative primes (e.g., Show the tiger the letter/Show the letter to the tiger)	Animate noun: Shake the frog up and down (distractor: frisbee)

Table 9
Analysis of looks to the animal for the fillers in Experiment 2a: Coarse temporal window

Effect	All blocks	Block 1 only	Blocks 2–4 only
Prime	$F(1,13) = 4.320^{\dagger}$	$F(1,12) = 7.664^{*}$	$F(1,11) = 0.457$
Target	$F(1,13) = 121.92^{**}$	N/A	$F(1,11) = 29.551^{**}$
Prime * Target	$F(1,13) = 0.491$	N/A	$F(1,11) = 0.047$

Note. $^{\dagger}p < .1$; $^{*}p < .05$; $^{**}p < .01$.

the animacy of the verb's theme. In contrast, the dative primes are semantically equivalent (the theme is always inanimate), so the two types of primes would have equivalent effects on the interpretation of transitive targets. Thus, conceptual or semantic priming may explain why transitives prime transitives and datives do not. However, since animacy priming of this kind cannot explain our primary dative-to-dative priming results, we would need to posit another mechanism to account for these findings. A second possibility is that animacy priming is based on linear order but is constrained by the nature of the verbs in the utterances (e.g., datives can only prime datives, and transitives can only prime transitives). Any account of this kind would invoke abstract structural categories (e.g., transitive or dative verb). Critically the restricted pattern of animacy priming is inconsistent with simple explanations relying solely on animacy and linear order, which would predict transfer from dative primes to transitive targets.

The remaining explanations all invoke syntax in one way or another. The simplest possibility is that our manipulation directly primed the syntactic structures used in double object (Verb Noun-Phrase Noun-Phrase) and prepositional (Verb Noun-Phrase Prepositional-Phrase) datives (Pickering & Branigan, 1998). These structures in turn would activate the thematic roles associated with them, which in turn would activate animacy features associated with those roles, resulting in the observed eye-movements. Alternately, our priming manipulation could have targeted the mapping between thematic roles or animacy features on the one hand and syntactic positions on the other. For example if the locus of the effect was the mapping of thematic roles, double-object primes would potentiate a recipient ↔ direct object mapping, while prepositional-object primes would potentiate a theme ↔ direct object mapping. Since the recipient and theme roles are in turn correlated with animacy (the recipient is usually animate, the theme is usually inanimate), this would give rise to the pattern of eye movements seen in our experiments. Alternately, direct mappings between animacy features and syntactic positions (e.g., animate ↔ direct object or inanimate ↔ direct object) may have been primed. However, as we noted above, any explanation invoking animacy would have to restrict priming to a mapping between animacy features and syntactic positions that is specific to a particular class of verbs (e.g., ditransitive verbs). All three of these forms of priming have been found in adults during sentence production (syntactic structures: Bock & Loebell, 1990; animacy mappings: Bock et al., 1992; thematic role mappings: Chang et al., 2003), thus we see no reason to favor one of these loci over the others.

In sum, while our measure of priming patently detects a prediction of the animacy of the direct-object noun, our results cannot be explained by a simple mapping between animacy and position without reference to verb classes, thematic roles or syntactic structure. Therefore, we conclude that all plausible interpretations of our results involve abstractions that are broader than individual verbs.

Exploring the mechanisms of structural priming in comprehension

These experiments and a companion study with adults (Thothathiri & Snedeker, 2007) are among the first demonstrations of abstract syntactic priming in comprehension (see also Scheepers & Crocker, 2004). While these studies were not designed to investigate the mechanisms of comprehension priming, our data offer some preliminary insights into these processes. Below we address three questions: (1) Could the effects of structural priming result from a deliberate strategy induced by the demands of our task? (2) Do the temporal properties of these effects suggest transient changes in the accessibility of representations or long-lasting changes in the stability of these representations? (3) At what point does the primed structure begin to influence the interpretation of the target sentence?

Could the priming effects be strategic?

The between-participants design used in the present experiment raises the issue of whether the effects of priming might be strategic. Perhaps over the course of the experiment the children developed the expectation that target sentences would be of the statistically predominant type (i.e., the prime type) and deployed their gaze accordingly. If by strategy we mean a deliberate activity employed to achieve a particular goal then this explanation seems unlikely given the age of the children that we tested. Preschoolers are notoriously poor at devising, selecting and employing new strategies (see Flavell, Miller, & Miller, 2002 for a review). For example, in short-term memory studies, young children rarely use simple but effective strategies like verbal rehearsal (Appel et al., 1972; Flavell, Beach, & Chinsky, 1966). When taught a new strategy, they often fail to benefit from its use (presumably because they find it difficult to deploy) and rarely generalize it to novel problems (Flavell & Wellman, 1977; Miller & Seier, 1994). In addition, the strategy in question appears to require more metalinguistic knowledge than preschoolers possess (Gombert, 1992). The animacy control condition demonstrates that children are not merely learning that the animate comes first (or last). Any strategy that could account for these data would have to invoke linguistic categories such as verb classes, thematic roles or syntactic structures (see above) which may not be consciously accessible prior to formal education.

While a deliberate strategy seems beyond the reach of preschoolers, it is worth considering whether the

observed effects could result from a more implicit adaptation to the task. There is ample evidence that children—like rats—can implicitly track the relative frequency of different events (Hasher & Zacks, 1979; Kelly & Martin, 1994). If the observed effects were attributable to probability tracking, then we might expect to see them emerge gradually as participants accumulate sufficient experience to estimate the relative frequency of the two sentence types. In contrast, if the effects reflect the influence of individual prime sentences on the processing of the targets, then we would expect these effects to be robust from the very first trial. We tested this possibility by looking for a priming effect on the first target trial in the critical across-verb priming experiment with the three-year-olds (Experiment 2b). We analyzed looks to the dispreferred item just as for the main analyses, but we used a non-parametric test because the distribution of the dependent measure was not normal. With this single-trial analysis, we still found a significant effect of prime [Mann–Whitney $U = 62.5$, $p = .021$]. As predicted, mean looks to the animal were higher in the double-object prime conditions (0.358) than in the prepositional-object prime conditions (0.156). Thus we reject the possibility that the priming observed in this study was merely an adaptation (explicit or implicit) to our between-participants design.

Is priming transient or long-lasting?

Much of the recent work on production priming in adults has focused on whether syntactic priming is best conceived of as a transient increase in activation (parallel to semantic priming) or a durable, but subtle, alteration in syntactic representations (parallel to implicit learning, see Bock & Griffin, 2000). Those who favor the transient activation account cite the short duration of priming in some paradigms and argue that implicit learning models fail to provide a satisfying explanation for lexically-specific effects (Branigan, 2007). Those favoring the implicit learning account note that syntactic priming can persist over as many as 10 intervening items (Bock & Griffin, 2000) and delays as long as 20 min (Boyland & Anderson, 1998). On this account, structural priming is simply a continuation of the learning process that allows children to master new syntactic constructions (see Chang, Dell, & Bock, 2006). Some support for this claim comes from a recent study demonstrating that massive exposure to the passive construction (in essence priming) increases the probability that four- and five-year-olds will produce passives in a subsequent session and decreases the error rate for passives in both comprehension and production (Vasilyeva, Huttenlocher, & Waterfall, 2006).

While the present studies were not designed to explore the persistence of priming, two aspects of our data may be relevant to understanding the temporal properties of priming in comprehension. First, the inter-trial interval in the current studies was quite long (30–60 s) and was filled with task-related conversation (a minimum of three sentences). Thus the temporal (and verbal) distance between the prime and target was similar to the lag conditions used in prior production studies that have been argued to support the implicit learning account.

Second, if priming is implicit learning then we would expect it to persist and accumulate over time. Our between-participants design allows us to begin to explore this possibility. As the experiment progresses, participants get repeated experience with a particular prime type. If the impact of this experience is cumulative, then the effect of prime type should increase across trials. To examine this, we compared priming in the first half to priming in the second half of the critical across-verb priming experiment with the three-year-olds (Experiment 2b). We performed a 2×2 ANOVA (Prime $\times$ Half) of children's looks to the animal in the same coarse temporal window as for the main analyses. There was a main effect of prime [$F(1,30) = 6.033$, $p < .05$] but no effect of half [$F < 1$, $p > .6$] and no interaction between half and prime [$F < 1$, $p > .6$]. In the first half, children in the double-object prime conditions looked more at the animal (0.297) than those in the prepositional-object prime conditions (0.191; CI for the 0.106 difference between means was ± 0.112). The effect was similar in the second half (double-object prime: 0.295; prepositional-object prime: 0.158; CI for the 0.137 difference between means was ± 0.130). Thus we find no evidence of cumulative effects in our experiments. However, these results by no means rule out the possibility that such effects exist. In our study, the priming effect during the earlier trials may have been close to ceiling making it impossible to detect any increase (see the first trial analysis in the previous section). In addition, the small number of trials may have provided a limited opportunity for priming to accumulate, reducing our chances of detecting any such increase.

When does priming begin to influence the interpretation of the target sentence?

Comprehension paradigms introduce a new temporal parameter into the study of structural priming. We can explore not only the duration of priming but also the point at which the priming manipulation begins to influence the interpretation of the target utterance. Our results clearly show that children make prime-consistent eye movements to the animal or object shortly *after* the onset of the noun. However a close examination of Figs. 2 and 4 suggests that the prime may have an effect even earlier; object looks in the two prime conditions appear to begin diverging at -100 ms, about 300 ms before information about the target noun becomes available. Such a pattern would not be completely surprising. Several recent studies have demonstrated that adults

anticipate the properties of a verb's arguments soon after hearing the verb and prior to hearing the arguments themselves (e.g., Altmann & Kamide, 1999; Boland, 2005). Arai et al. (2005) found that anticipatory eye-movements following a dative verb were influenced by within-verb priming (but not between-verb priming). Double-object primes resulted in more looks to potential recipients while prepositional-object primes resulted in more looks to potential themes. Since both forms of the dative share the same thematic roles this finding suggests that anticipatory looks are conditioned on the order of the arguments in the structure that is retrieved.

To explore whether abstract structural priming has a parallel effect on the initial retrieval of verb argument structure in young children, we analyzed the time-window between the onset of the verb (which is also the onset of the sentence) and the onset of the ambiguous noun (with a 200 ms offset) for the critical across-verb experiment with the three-year-olds (Experiment 2b). The temporal window extended from −467 to 167 ms relative to noun-onset. Because this time-window precedes any phonological information about the noun, we analyzed the sum of looks to both animals in the visual scene, rather than focusing solely on the critical animal. Forty five percent of the trials were excluded because the children were not looking at any of the items. The sum of looks to both animals was numerically higher in the double-object-prime conditions (0.387) than in the prepositional-object-prime conditions (0.283; CI for the 0.104 difference between means was ±0.215), but the effect was not significant [$F(1,25) = 0.998$, $p = .327$]. It is not clear however that we would expect an effect that was triggered by the verb to emerge this rapidly in the three-year-olds: recall that the average latency to look to the referent of an unambiguous noun was 983 ms for this group. For this reason we also performed pre-noun analyses for the between-verb experiment with the four-year-olds, who had more rapid response latencies (437 ms). The temporal window for this analysis extended from −233 to +167 ms relative to noun-onset. In this study the object was the dispreferred item, so we analyzed the sum of looks to both objects. Thirty one percent of the trials were excluded because the children were not looking at any of the items. The sum of looks to both objects was greater in the prepositional-object prime conditions (0.489) than in the double-object prime conditions (0.350; CI for the 0.139 difference between means was ±0.153) and this effect was marginally significant [$F(1,33) = 3.370$, $p = .075$].

Thus we find tentative evidence that priming influences four-year-olds' anticipatory eye-movements but no evidence for an effect in three-year-olds. This could be a result of the stimuli and measures that were used in each study, the children's level of attention to the task, differences in eye-movement latencies, or differences in the early processing of verbs. Two aspects of our task make it ill-suited for exploring anticipatory eye-movements: (1) the verb always occurred at the very beginning of the target utterance (possibly reducing task-driven looking during this time window) and (2) our displays included two potential themes and two potential recipients, each of which is moderately and equally plausible given the verb (leading to ambiguity in how the retrieved argument structure maps onto the visual scene). Consequently, a full understanding of the early temporal dynamics of children's verb processing must await future investigation.

Comparison to previous studies

Our results add to the existing literature on the abstractness of children's linguistic representations in several ways. First, they demonstrate children's use of abstract representations in a situation where they know the verbs and thus could presumably rely solely on lexically-specific representations, were this their dominant form of grammatical representation. Thus, they complement novel-verb comprehension studies, which show that children can generalize attested structures to new verbs. They provide converging evidence that children have the capacity for structural abstractions and extend this work by showing that children *use* these abstractions during online comprehension. Second, these results add to the nascent literature on structural priming in three- and four-year-old children. Our methodology rules out at least one alternate explanation for production-priming (priming of closed class items). Third, our results bear on possible differences between comprehension and production. Previous studies in both adults and children have shown that prior comprehension influences subsequent production (e.g., Allopenna et al., 1998; Huttenlocher et al., 2004). This suggests that there are structural representations or processes that are common across comprehension and production. However, some have suggested that these representations are employed differently *during* comprehension and production (Arai et al., 2005). Specifically, it has been proposed that comprehension (unlike production) may be guided exclusively by lexically-specific syntactic information. Our results show that children also use *abstract* syntactic information during the comprehension of datives.

How can we reconcile our findings with prior studies of children's novel-verb production? One possibility would be to extend recent proposals by usage-based theorists that different tasks tap representations of different strength. For example, Tomasello and Abbot-Smith (2002, p. 212) suggest that "linguistic and other cognitive representations grow in strength during ontogeny, and performance in preferential looking tasks requires only weak representations whereas performance in tasks requiring more active behavioral decision making

requires stronger representations." Perhaps weak abstract representations also suffice to cause the across-verb comprehension priming reported here.

If this were true we would expect to see two patterns in our data, neither of which is present. First, the between-verb priming effect should initially be small relative to the within-verb priming effect (since novel-verb production tasks provide robust evidence for verb-specific generalizations and only weak evidence for syntactic generalizations in two- and three-year-olds). However, we find that three-year-olds show a robust between-verb priming effect that is not significantly (or substantially) smaller than the within-verb priming effect (see Table 7). Second, if abstract representations grow stronger over development, then the size of the across-verb priming effect, relative to the within-verb effect, should increase with age. While a direct comparison between the age groups is complicated by differences between the two studies, our data provide no support for this account. In fact, the advantage for within-verb priming is numerically greater in the study of the four-year-olds than it is in the study of the three-year-olds (see Experiment 2, Discussion). Thus our results do not support the graded strength hypothesis. Below, we describe how structural priming can be used to investigate an alternate explanation which has been widely accepted in the field of adult sentence processing.

Integrating lexical-specificity into theories with abstract syntactic representations: Lessons from online processing

The structural priming technique offers promise for exploring the theoretical and developmental issues raised in the Introduction. Theoretical work on argument structure has consistently acknowledged both broad syntax–semantics correspondences and the role that lexical information plays in the syntactic realization of event structure (Dowty, 1991; Jackendoff, 2002; Levin, 1993). Developmentally, there is a tension between evidence for early abstract representations (e.g., Fisher, 2002b) and item-specific use (e.g., Tomasello, 2000a) in children. Studying the links between children's lexical and abstract representations may be a fruitful avenue for resolving these questions. Lexical-specificity and abstract syntax have long been accepted and reconciled in theories of adult sentence comprehension. The data have left us with little choice. For example, Trueswell and Kim (1998) found that reading times for temporarily ambiguous sentence complements like (2) were affected by brief exposures (39 ms) to one-word primes.

2. The photographer accepted the fire could not be put out.

Exposure to a verb that typically takes a sentence complement (e.g., *realize*) facilitated ambiguity resolution, while exposure to a verb that typically takes a direct object (e.g., *obtain*) hindered it. Clearly this effect can only take place in a representational system which is both lexically-specific (different verbs had different impacts) and abstract (the structural biases of one verb affected processing of another). Like many in the field, Trueswell and Kim accounted for these findings by positing that individual verbs are associated with abstract structural representations (syntactic and semantic) which can be primed (MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994). The strength of the link between the verb and a structural node depends on learners' prior exposure to that particular verb in that particular syntactic context. Models of this kind provide an explanation for the coexistence of generalization and item-specificity in young children (see Fisher, 2002b). Perhaps young children, like adults, have abstract syntactic representations, abstract semantic representations, and mappings between the two. However, depending on their experience with individual verbs, the *connections* between any given verb and some abstract structures may be weak or even absent. Were this true, we'd expect children to succeed when knowledge of the abstract structure alone was sufficient to solve the problem. This is generally the case in novel verb preferential looking studies (e.g., Fisher, 2000), where the structure is provided and it is sufficient to interpret the utterance without integrating verb specific information. However, when the task requires the child to use the connection between the verb and the structure, we would expect that performance would depend upon (1) the child's prior experience of the verb in that structure and (2) their experience of the verb in alternate structures (competition effects). Novel-verb production studies put the child in precisely the situation where she is least likely to be able to link the verb to the new structure: there is no prior association between the two and there is a strong association between the verb and an alternate structure. In contrast, known verb priming studies, like the one reported here, allow the child to make use of previously acquired associations between specific verbs and abstract structures.

The model outlined above appears to account for findings from three different strands of research—novel-verb comprehension, novel-verb production and structural priming. However it does not offer a simple explanation for why older children (and adults) do better than younger children in the novel-verb production studies, even though they too lack a specific association between the verb and the structure. We see three potential classes of explanations. First, older children may have less difficulty inhibiting the strong link between the verb and the attested argument structure. For example, four-year-olds do better than three-year-olds at

tasks requiring the inhibition of prior responses (Zelazo, Frye, & Rapus, 1996). Second, they may be more sensitive to the discourse manipulations typically used to elicit the target syntactic frames. Third, they may have more knowledge about specific verb subclasses in their language (see Brooks & Tomasello, 1999b), and thus be more adept at inferring that a verb can appear in one structure, given its meaning or its appearance in another structure.

Conclusions

In this paper, we found that children's online interpretation of a dative sentence with a temporary argument structure ambiguity was influenced by prior dative sentences. This priming effect was seen both in three-year-olds and four-year-olds, when the same verb was used in different sentences, and when different verbs were used. The across-verb priming results demonstrate that children as young as three years employ abstract representations during the comprehension of sentences with known verbs.

Future studies can shed light on important questions that remain. These include the precise nature of the representations that can be primed (semantic, syntactic, or mappings between syntax and semantics), and the constraints on priming between verbs (is priming restricted to verbs with similar distribution, similar meaning, or both?). Most importantly, future priming studies can elucidate whether young children like adults, have a language processing system in which lexical and abstract representations interact to produce both item-specific and generalized patterns of use.

Acknowledgments

We thank Cynthia Fisher for helpful discussions, Steven Pinker for comments on an earlier manuscript, Stefan Th. Gries for sharing corpus analyses of datives, and Sneha Rao, Jane Sung, Adrianna Saada and Megan Powell for their assistance in collecting and coding data.

Appendix

Target sentences (Experiment 1)

Double-object	Prepositional-object
Give the doll the cat food	Give the dollhouse to the bunny
Give the bird the dog bone	Give the birdhouse to the sheep
Give the pig the cat food	Give the pigpen to the tiger
Give the fish the dog bone	Give the fishbowl to the bear

Target sentences (Experiment 2: Group 1/Group 2)

Double-object	Prepositional-object
Pass/Hand the cow the brush	Pass/Hand the couch to the tiger
Send/Show the horse the book	Send/Show the horn to the dog
Throw/Toss the sheep the orange	Throw/Toss the shoe to the frog
Bring/Take the monkey the hat	Bring/Take the money to the bear

References

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory & Language, 38*, 419–439.

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition, 73*, 247–264.

Appel, L. P., Cooper, R. G., McCarrell, N., Sims-Knight, J., Yussen, S. R., & Flavell, J. H. (1972). The development of the distinction between perceiving and memorizing. *Child Development, 43*, 1365–1381.

Arai, M., Van Gompel, R. P. G., & Scheepers, C. (2005). Priming ditransitive structures in comprehension. *Paper presented at the 18th annual CUNY sentence processing conference*. Tucson, AZ.

Baker, M. (1988). *Incorporation: A theory of grammatical function changing*. Chicago: University of Chicago Press.

Baker, M. (1997). Thematic roles and syntactic structure. In L. Haegeman (Ed.), *Elements of grammar* (pp. 73–137). Dordrecht: Kluwer.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*, 355–387.

Bock, K., & Loebell, H. (1990). Framing sentences. *Cognition, 35*, 1–39.

Bock, K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review, 99*, 150–171.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning?. *Journal of Experimental Psychology: General 129*, 177–192.

Boland, J. (2005). Visual arguments. *Cognition, 95*, 237–274.

Bowerman, M. (1990). Mapping thematic roles onto syntactic functions: Are children helped by innate linking rules? *Linguistics, 28*, 1253–1289.

Bowerman, M. (1973). *Early syntactic development: A cross-linguistic study with special reference to Finnish*. Cambridge: Cambridge University Press.

Boyland, J. T. & Anderson, J. R. (1998). Evidence that syntactic priming is long-lasting. In *Proceedings of the twentieth annual conference of the cognitive science society* (p. 1205). Hillsdale, NJ: Erlbaum.

Braine, M. (1963). The ontogeny of English phrase structure: The first phase. *Language, 39*, 1–13.

Braine, M. D. S. (1976). Children's first word combinations. *Monographs of the Society for Research in Child Development, 41* (1, Serial No. 164).

Braine, M. D. S. (1992). What sort of innate structure is needed to "bootstrap" into syntax? *Cognition, 45*, 77–100.

Branigan, H. P., Pickering, M. J., Stewart, A. J., & McLean, J. F. (2000). Syntactic priming in spoken production: Linguistic and temporal interference. *Memory & Cognition, 28*, 1297–1302.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition, 75*, B13–B25.

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming prepositional-phrase attachment during comprehension. *Journal of Experimental Psychology: Learning, Memory & Cognition, 31*, 468–481.

Branigan, H. P., McLean, J. F., & Jones, M. W. (2005). A blue cat or a cat that is blue? Evidence for abstract syntax in young children's noun phrases. In *Proceedings of the 29th annual Boston university conference on language development* (pp. 109–121). Somerville, MA: Cascadilla Press.

Branigan, H. P. (2007). Syntactic priming. *Language and Linguistics Compass, 1*(1–2), 1–16.

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

Brooks, P. J., & Tomasello, M. (1999b). How children constrain their argument structure constructions. *Language, 75*, 720–738.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Campbell, A. L., & Tomasello, M. (2001). The acquisition of English dative constructions. *Applied Psycholinguistics, 22*, 253–267.

Chang, F., Bock, K., & Goldberg, A. E. (2003). Can thematic roles leave traces of their places? *Cognition, 90*, 29–49.

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

Collins, P. (1995). The indirect object construction in English: An informational approach. *Linguistics, 33*, 35–49.

Conwell, E., & Demuth, K. (2007). Early syntactic productivity: Evidence from dative shift. *Cognition, 103*, 163–179.

Dixon, R. M. W. (1994). *Ergativity*. Cambridge: Cambridge University Press.

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

Fernald, A., Zangl, R., Thorpe, K., Hurtado, N., & Williams, C. (2006). Learning to listen ahead in English and Spanish: Infants use multiple linguistic and non-linguistic cues in online sentence interpretation. *Paper presented at the online methods in children's language processing workshop*. New York, NY.

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.

Fillmore, C. J. (1968). The case for case. In E. Bach & R. T. Harms (Eds.), *Universals in linguistic theory* (pp. 1–88). New York: Holt, Rinehart and Winston.

Fisher, C., Gleitman, H., & Gleitman, L. R. (1991). On the semantic content of subcategorization frames. *Cognitive Psychology, 23*, 331–392.

Fisher, C., Hall, 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. (2000). Who's blicking whom? Word order influences toddlers' interpretations of novel verbs. *Paper presented at the 11th international conference on infant studies*. Brighton, UK.

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. *Cognition, 82*, 259–278.

Flavell, J., Miller, P., & Miller, S. (2002). *Cognitive development* (6th ed.). Upper Saddle River, NJ: Prentice Hall.

Flavell, J. H., Beach, D. R., & Chinsky, J. H. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development, 37*, 283–299.

Flavell, J. H., & Wellman, H. M. (1977). Metamemory. In R. V. Kail, Jr. & W. Hagen (Eds.), *Perspectives on the development of memory and cognition*. Hillsdale, NJ: Erlbaum.

Gamez, P. B., Shimpi, P. M., & Huttenlocher, J. (2005). Emerging syntactic representations as evident through priming. *Poster presented at the 2005 SRCD biennial meeting*. Atlanta, GA.

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.

Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition, 73*, 135–176.

Gleitman, L. (1990). The structural sources of word meaning. *Language Acquisition, 1*, 3–55.

Goldberg, A. (1995). *Constructions: A construction grammar approach to argument structure*. Chicago: University of Chicago Press.

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

Gombert, J. (1992). *Metalinguistic development*. New York: Harvester/Wheatsheaf.

Gries, S. T., & Stefanowitsch, A. (2004). Extending collostructional analysis: A corpus-based perspective on 'alternations'. *International Journal of Corpus Linguistics, 9*, 97–129.

Grimshaw, J. (1990). *Argument structure*. Cambridge, MA: MIT Press.

Grimshaw, J. (1981). Form, function, and the language acquisition device. In C. L. Baker & J. McCarthy (Eds.), *The logical problem of language acquisition* (pp. 165–182). Cambridge, MA: MIT Press.

Gropen, J., Pinker, S., Hollander, M., Goldberg, R., & Wilson, R. (1989). The learnability and acquisition of the dative alternation in English. *Language, 65*, 203–257.

Hasher, L., & Zacks, R. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*, 356–388.

Henderson, J. M., & Ferreira, F. (2004). *The interface of language, vision, and action: Eye movements and the visual world*. New York: Psychology Press.

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

Huttenlocher, J., Vasilyeva, M., & Shimpi, P. (2004). Syntactic priming in young children. *Journal of Memory and Language, 50*, 182–195.

Jackendoff, R. (2002). *Foundations of language—brain, meaning, grammar, evolution*. Oxford: Oxford University Press.

Kelly, M. H., & Martin, S. (1994). Domain-general abilities applied to domain-specific tasks: Sensitivity to probabilities in perception, cognition, and language. *Lingua, 92*, 105–140.

Konopka, A., & Bock, K. (2005). Helping syntax out: How much do words do? *Paper presented at the 18th annual CUNY sentence processing conference*. Tucson, AZ.

Levin, B. (1983). *On the nature of ergativity*. Ph.D. dissertation, MIT.

Levin, B. (1993). *English verb classes and alternations*. Chicago: University of Chicago Press.

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review, 101*, 676–703.

Marantz, A. (1984). *On the nature of grammatical relations*. Cambridge, MA: MIT Press.

Masson, M. E., & Loftus, G. R. (2003). Using confidence intervals for graphically based data interpretation. *Canadian Journal of Experimental Psychology, 57*, 202–220.

Matin, E., Shao, K. C., & Boff, K. R. (1993). Saccadic overhead: Information-processing time with and without saccades. *Perception & Psychophysics, 53*, 372–380.

McNeill, D. (1966). Developmental psycholinguistics. In F. Smith & G. A. Miller (Eds.), *The genesis of language: A psycholinguistic approach*. Cambridge, MA: MIT Press.

Miller, P. H., & Seier, W. L. (1994). Strategy utilization deficiencies in children: When, where, and why. In H. W. Reese (Ed.). *Advances in child development and behavior* (Vol. 25, pp. 107–156). New York: Academic Press.

Ninio, A. (2005). Testing the role of semantic similarity in syntactic development. *Journal of Child Language, 32*, 35–61.

Ninio, A. (1999). Pathbreaking verbs in syntactic development and the question of prototypical transitivity. *Journal of Child Language, 26*, 619–653.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory & Language, 39*, 633–651.

Pinker, S. (1984). *Language Learnability and Language Development*. Cambridge, MA: Harvard University Press.

Potter, M. C., & Lombardi, L. (1998). Syntactic priming in immediate recall of sentences. *Journal of Memory and Language, 38*, 265–282.

Savage, C., Lieven, E., Theakston, A., & Tomasello, M. (2003). Testing the abstractness of children's linguistic representations: Lexical and structural priming of syntactic constructions in young children. *Developmental Science, 6*, 557–567.

Savage, C., Lieven, E., Theakston, A., & Tomasello, M. (2006). Structural priming as implicit learning in language acquisition. *Language Learning & Development, 2*, 27–49.

Scheepers, C. (2003). Syntactic priming of relative clause attachments: Persistence of structural configuration in sentence production. *Cognition, 89*, 179–205.

Scheepers, C., & Crocker, M. W. (2004). Constituent order priming from reading to listening: A visual-world study. In M. Carreiras & C. J. Clifton (Eds.), *The on-line study of sentence comprehension: Eyetracking, ERP and beyond* (pp. 167–185). Hove: Psychology Press.

Slobin, D. I. (1985). Cross-linguistic evidence for the language-making capacity. In D. Slobin (Ed.). *The crosslinguistic study of language acquisition* (Vol. 2, pp. 1157–1256). Englewood Cliffs, NJ: Lawrence Erlbaum.

Snedeker, J., & Gleitman, L. (2004). Why it is hard to label our concepts. In D. G. Hall & S. R. Waxman (Eds.), *Weaving a lexicon* (pp. 255–293). Cambridge, MA: MIT Press.

Snedeker, J., & Trueswell, J. C. (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.

Snedeker, J., & Yuan, S. (in press). The development of interactive parsing: Children use lexical and prosodic cues in online sentence comprehension. *Journal of Memory and Language*, doi:10.1016/j.jml.2007.08.001.

Song, H.-J., & Fisher, C. (2004). Syntactic priming in 3-year-old children. *Paper presented at the 29th annual Boston university conference on language development*. Boston, MA.

Swingley, D., Pinto, J. P., & Fernald, A. (1999). Continuous processing in word recognition at 24 months. *Cognition, 71*, 73–108.

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.

Thothathiri, M., & Snedeker, J. (2006). Structural priming during comprehension of datives. *Poster presented at the 19th annual CUNY conference on human sentence processing*. New York, NY.

Thothathiri, M., & Snedeker, J. (submitted for publication). Give and take: Syntactic priming during spoken language comprehension.

Tomasello, M. (1992). *First verbs: A case study in early grammatical development*. Cambridge: Cambridge University Press.

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

Tomasello, M. (2000b). The item-based nature of children's early syntactic development. *Trends in Cognitive Sciences, 4*, 156–163.

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

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

Tomasello, M., & Akhtar, N. (2003). What paradox? A response to Naigles (2002). *Cognition, 88*, 317–323.

Trueswell, J., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The kindergarten-path effect: Studying on-line sentence processing in young children. *Cognition, 73*, 89–134.

Trueswell, J. C., & Kim, A. E. (1998). How to prune a garden-path by nipping it in the bud: Fast-priming of verb argument structures. *Journal of Memory and Language, 39*, 102–123.

Trueswell, J. C., & Tanenhaus, M. K. (1994). Toward a lexicalist framework of constraint-based syntactic ambiguity resolution. In C. J. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 155–179). Hillsdale, NJ: Lawrence Erlbaum.

Vasilyeva, M., Huttenlocher, J., & Waterfall, H. (2006). Effects of language intervention on syntactic skill levels in preschoolers. *Developmental Psychology, 42*, 164–174.

Yuan, S., Fisher, C.L., Gertner, Y., & Snedeker, J.C. (2007). Participants are more than physical bodies: 21-month-olds assign relational meaning to novel transitive verbs. *Paper Presented at the 2007 SRCD Biennial Meeting*. Boston, MA.

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development, 11*, 37–63.