

## **Chapter 5**

### **What Lurks Beneath: Syntactic Priming During Language Comprehension in Preschoolers (and Adults)**

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#### **1 Introduction**

In the past ten years researchers have made extensive use of online methods to explore what children understand at different ages, how rapidly they understand it, and what kinds of information they use to reach this understanding. Our recent work brings together two existing methods (syntactic priming and the world-situated eye-gaze paradigm) to explore a different question: What is the nature and scope of young children's grammatical representations and how do they change over development? We begin by briefly reviewing alternate theories about development of syntax and its mapping to semantics. Next we describe the phenomenon of syntactic priming during production, before introducing our method for exploring priming during spoken language comprehension. We then describe a series of experiments on syntactic priming from comprehension to comprehension in adults, four-year-olds and three-year-olds. In each

case we find robust evidence that participants' interpretation of utterances is influenced by the structure of prior utterances even in the absence of lexical overlap. These results indicate that young children (and adults) employ abstract structural representations during online sentence comprehension. Finally we discuss how this technique can be used to explore the nature of these abstract representations and their relation to individual lexical items.

*1.1 The Acquisition of Argument Structure: Early Abstraction or Item-based Frames?*

A perennial question in 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). Any theory of these relations must account for two facts. First, there are systematic linkages between meaning and syntactic structure that are robust across verbs and languages (Fillmore, 1968; Baker, 1988; Dowty, 1991; Levin, 1993). For example agents of actions generally surface as subjects, and themes as direct objects. Second, although these linkages are systematic, they do not fully predict the syntactic position of an argument. Similar propositions can be expressed using different surface syntactic forms, depending on the verb, its

morphological form and other factors such as discourse structure and the phonological weight of constituents (1-2). Since much of this variation depends upon the verb in the utterance, all viable theories make use of lexically-specific information (though they vary in whether it is syntactic or semantic and how it is used).

- (1) a. The possible housing collapse frightened the young couple.  
b. The young couple feared the possible housing collapse.
- (2) a. Ariel sent a half-eaten pomegranate to Chris.  
b. Ariel sent Chris a half-eaten pomegranate.

While every theory of language acquisition must acknowledge these two facts, theorists differ in which they see as primary. For one group of theorists, the robustness of the syntactic-semantic correspondences is seen as evidence that the linkages between meaning and structure are innate properties of universal grammar that play a role in language acquisition (Grimshaw, 1981; Pinker, 1984; Gleitman, 1990). For example, Pinker's semantic bootstrapping hypothesis (1984) proposes that children come to the task of language acquisition with a set of thematic roles (e.g., agent and patient), a set of syntactic functions (e.g., subject and direct object), and some default rules for linking one to the other.

In contrast, usage-based theories place lexically-specific information at the center of acquisition (Tomasello, 1992; Goldberg, 1995). For example, Tomasello proposes that children initially analyze each predicate as an isolated grammatical island with open argument positions that can be freely filled with nominals. Gradually children begin to notice similarities in the semantic functions assigned to these fillers and 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. This account differs from the semantic bootstrapping hypothesis in two ways. First, the semantic bootstrapping hypothesis proposes that children who are just beginning to learn language 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. These two features are partially independent. While innate mapping rules presuppose abstractions of roughly the same scope as the target grammar, the converse need not be true. Syntactic and semantic abstractions may guide children's early language acquisition even if the mappings between them must be learned.

In fact the notion that children's early grammars employ broad categories is shared by many theories which dispute the notion of innate or early-acquired thematic mapping rules. For example, Braine (1976), Bowerman (1973), and others have suggested that early child language is organized around conceptual categories (e.g., action, actor) which serve as an entry point into syntax. Goldberg (2006) emphasizes the learning of syntax-semantic mappings but nevertheless suggests that children have semantic generalizations (such as actor) and syntactic slots (like PP) from very early on. These theories all posit an early grammar with abstract categories that could support generalizations across verbs, thus they contrast with usage-based theories that claim early grammars lack such categories before three- to three-and-a-half years of age.

Much of the recent research on these issues has addressed both questions simultaneously, searching for evidence that young children have thematic mapping rules that express relations between abstract syntactic and semantic categories. In contrast our work puts aside the question of whether young children have these linking rules and simply focuses on whether they have abstract categories. 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. Before introducing the priming paradigm, we

briefly discuss findings from other methods for exploring children's structural generalizations.

### *1.2 Novel-Verb Generalization as a Window onto Grammatical Representations*

Recent work on the nature of children's structural representations has focused on their ability to comprehend and produce sentences with novel verbs. An impressive number of production experiments have demonstrated that children under three-and-a-half primarily use new verbs in ways that mimic the input, failing to generalize argument structure alternations from one verb to another (see Tomasello, 2000 for a review). For example, Tomasello & Brooks (1998) presented two-year-old children with a novel verb in either a transitive or an intransitive construction (e.g., *The puppy is meeking the ball* or *The ball is meeking*) and then attempted to elicit the unmodeled construction. For example, intransitives were elicited by asking questions which placed the theme in subject position, ensuring that it would be given information in any response (*What did the ball do?*). Despite this discourse pressure, the children used the construction that had been modeled by the adult almost 90 percent of the time. The authors concluded that children's early constructions are verb-

specific, and that abstract verb-general constructions develop gradually during the preschool years.

In contrast, several novel-verb comprehension studies have found evidence for abstract constructions in children between 20 and 36 months of age. These studies explore generalization by testing whether young children can use broad semantic-syntactic mappings to interpret the thematic roles assigned by a novel verb. For example, Fisher and colleagues have found that children as young as 20 months systematically 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 & Snedeker, 2007). Further evidence comes from children's comprehension of reversible transitives. By 21 months of age, children systematically interpret the subject of a transitive sentence with a novel verb as the agent of the action (Gertner, Fisher & Eisengart, 2006).

How can we reconcile the productivity present in these comprehension studies with the lack of generalization observed in the production studies? Most authors suggest that one set of findings reveals the child's workaday grammar, while the other reflects task-specific strategies or limitations. For example, Tomasello and colleagues have suggested that the preferential-looking studies may reflect emerging and incomplete representations that initially play little role in everyday

comprehension and production (see e.g., Savage, Lieven, Theakston & Tomasello, 2003). In contrast Fisher (2002b) has argued that low productivity during novel verb production cannot be taken as evidence for the absence of abstract representations. Whether a verb can appear in a particular argument structure alternation depends on a complex set of semantic constraints (Levin, 1993). For example, the causative alternation, used by Tomasello and Brooks (1998), is restricted to verbs that encode an externally-caused manner of motion. Consequently, even a learner with abstract representations of argument structure might be unwilling to extend novel verbs to unattested constructions because she lacks full knowledge of the semantic constraints on the alternation or is uncertain about the meaning of the verb. While the children in these production studies clearly map the verbs to appropriate events, it is unclear how precisely their interpretation of the verb matches the one that the experimenters had in mind. Extracting the meaning of a novel verb from a visual scene is difficult even for adults (Gillette, Gleitman, Gleitman & Lederer, 1999; Snedeker & Gleitman, 2004).

While the novel verb paradigms have been extremely informative, they have two limitations which have led researchers to seek out other methods. First, these paradigms necessarily explore children's structural representations by probing their knowledge of thematic linking rules. To generalize an argument structure alternation or interpret a sentence with a

novel verb, a child must know how semantic roles are mapped onto syntactic positions. But as we noted earlier, while structural abstractions are necessary for adult-like linking rules, linking rules are not necessary for abstractions. Thus a paradigm which allows us to investigate abstractions without requiring knowledge of mapping rules would be valuable.

Second, some have questioned the conclusions that can be drawn from novel-verb paradigms. For example, Ninio (2005) argues that children's ability to use or interpret novel verbs in unattested constructions does not necessarily demonstrate that they have linguistic representations which are abstract. Instead she suggests that children's grammatical knowledge is stored in a format that is lexically specific and concrete. However, 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 gorpung 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 structural generalizations that the verb island hypothesis denies. However it would

also be possible to form such an analogy without invoking higher-level linguistic categories. Children could simply translate or substitute a novel verb with a known form that has the same apparent meaning (e.g., *gorp* means *pull*). This would allow them to apply item-specific knowledge without invoking larger generalizations. Thus knowing that knowledge is transferred from a known verb to a novel verb leaves does not tell us about the nature of the representations that underlie this transfer or the knowledge that children draw upon in their comprehension and production of known words. Below, we discuss how syntactic priming paradigms can help shed light on these workaday structural representations.

## **2 Using Syntactic Priming to Study Abstraction in Children's Production**

In an elegant and extensive series of experiments, Bock has demonstrated that, in adult speakers, prior use of a syntactic construction alters the probability that it will be used again (Bock, 1986; Bock, 1989; Bock & Loebell, 1990; Bock, Loebell & Morley, 1992). For example, adults who have just produced a prepositional-object dative (PO e.g., *The girl handed a paintbrush to the man*) are relatively more likely to describe another picture using a second PO dative, while those who have just produced a double-object dative (DO e.g., *The girl handed the man a paintbrush*) are

relatively more likely to describe the picture with a DO dative. 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. In addition to picture-description, priming has been demonstrated during written sentence completion, spoken sentence completion, and dialogue with a confederate (Branigan, Pickering, Stewart & McLean, 2000; Branigan, Pickering & Cleland, 2000; Pickering & Branigan, 1998). This priming is not due to lexical or prosodic similarity alone (Bock & Loebell, 1990). The priming persists regardless of whether the speaker produces the prime or merely reads or hears it, demonstrating that these effects arise from the activation of structural representations or procedures that are common to both production and comprehension.

This technique has several advantages for studying the nature of children's structural representations. First, it allows us to explore how children use *known* verbs under controlled conditions. While novel-verb tasks are an effective way to control for prior verb-specific learning, interpreting their relevance for language processing may not be straightforward. 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 with known verbs (for which children presumably possess

adequate lexically-specific representations), we can better evaluate the importance of abstract representations in children's everyday language use.

Second, this technique allows us to compare the relative strength of abstract and lexically-specific priming. We can assess this by comparing the priming effects under two conditions: 1) when there is no lexical overlap between the prime and target (e.g., Prime: The boy threw his dog a ball, Target: The teacher gave the student new books); and 2) when the prime and target sentences share the same verb (e.g., Prime: The boy gave his dog a ball, Target: The teacher gave the student new books). In adults priming is stronger when there is lexical overlap (Pickering & Branigan, 1998 but see Konopka & Bock, 2005). This suggests either that adults are using lexically-specific representations in addition to abstract ones, or that lexical items are connected to abstract representations by links which can themselves be primed (see section 7.2). By comparing the strength of structural priming between verbs and structural priming within verbs, we can elucidate the relation between lexical and abstract processes in children and we can explore how both processes change over development. This may help reconcile the competing findings from the novel-verb production and comprehension studies.

Structural priming has only recently been used to study the nature of young children's representations. We are aware of four published

studies that explore production priming in children. One examined the production of noun phrases in three- and four-year-olds using a confederate dialog paradigm (Branigan, McLean & Jones, 2005). The children showed strong abstract priming which was further enhanced when the prime and target shared the same head noun. While this study suggests developmental continuity in priming, it does not address the questions that motivate the current work. The controversy in language acquisition centers on the status of verbs in the grammars of young children. The psychological reality of nouns is uncontentious (for example, the verb island hypothesis posits a category of nouns that fill in the slots of lexically-specific verbal frames).<sup>1</sup>

The remaining three studies used a picture description paradigm. In this paradigm, participants are shown pictures of simple scenes. During the prime trials the scene is described for the participant, who is typically asked to repeat this description. The prime trial is immediately followed by a test trial during which the participant is simply shown a picture and asked to describe it. Critically, both the prime and test pictures depict events which could be described using two syntactically distinct forms (e.g., DO and PO datives or the passive and active forms of the transitive).

The picture description studies with children differ from those with adults in several respects. First, studies with children typically employ a small number of test items. While this helps to ensure that the study is

short enough to be completed before the child's attention wanders, it prevents the experimenters from ascertaining whether the observed effects are robust across items. Second, for the same reason, few if any filler items are used. Finally, the critical independent variables are often manipulated between subjects (rather than within subjects) or blocked and presented in separate testing sessions. In adult studies, fillers and within subject manipulations are used to decrease the probability that participants will become aware of the critical manipulation and develop strategies specific to the experimental situation. Given the limited metalinguistic abilities of preschoolers (Gombert, 1992), developmentalists are typically not concerned about this possibility. However, note that both of these changes could increase the amount of priming in the child studies. If all the primes are of the same type for a given participant and these trials are interrupted by few or no filler items then priming from one trial may linger and summate with priming from the next.

The first study to explicitly explore priming in young children 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*). Six-year-olds showed priming in both overlap conditions, but three- and four-year-olds showed priming in the high overlap condition only. Thus the authors concluded that while six-year-olds have abstract representations, three- and four-year-olds primarily rely on lexically-specific representations involving pronouns and some grammatical morphemes. In contrast, Huttenlocher and colleagues found abstract structural priming in four- and five-year-olds for both transitive and dative constructions (Huttenlocher, Vasilyeva & Shimpi, 2004). While, these studies differed in several respects, two factors seem particularly relevant. The first is the number of times that the prime was repeated. The children in the Huttenlocher study heard each prime utterance just once, while those in the Savage study heard it four times. Repetition of a single utterance may primarily engage the mechanisms responsible for lexically-specific priming (e.g., verbal memory see Konopka & Bock, 2005), resulting in little or no abstract priming. A subsequent study by Savage and colleagues provides some preliminary support for this possibility (Savage, Lieven, Theakston & Tomasello, 2006). They found that older four-year-olds (mean age 4;11) showed weak priming effects when a single prime was used repeatedly, but showed robust priming when a variety of primes were employed. The second critical difference in the prior studies on abstract verbal priming is the exact age of the participants. The four-year-olds in the Huttenlocher study were older than those in the

Savage study (mean age of 4;8 as compared to 4;2). Thus the discrepancy could be explained if we assume that abstract production priming emerges sometime around four and a half. However, recent unpublished reports of production priming in younger children complicate this picture. Gamez, Shimpi, & Huttenlocher (2005) found no structural priming of datives in a picture description task with three-and-a-half- to four-and-a-half-year-olds, while Song & Fisher (2004) found robust structural priming in three-year-old children using a sentence imitation task.

### **3 Studying Priming during Comprehension**

Recent work in our lab explores syntactic priming during online comprehension. 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. These studies use a visual-world paradigm that taps online sentence processing. We measure participants' eye movements while they listen to instructions and manipulate objects. Under such 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

(Trueswell, Sekerina, Hill & Logrip, 1999; Snedeker & Trueswell, 2004; Snedeker & Yuan, in press; and Trueswell, this volume). By using a technique with good temporal resolution, we can explore the locus of the priming effect and rule out alternate explanations that might apply to priming during production.

### 3.1 *The Poor Man's Eye-tracker*

Most researchers employing the visual world paradigm use head-mounted or table-mounted eye-trackers to measure fixation patterns (see Trueswell this volume). In our lab we use a method we call the poor man's eyetracker, in which a hidden camera is used to videotape the participants direction of gaze. The set-up is simple. The participant sits in front of an inclined podium with four shelves, one in each quadrant. A camera is placed beneath the podium with its lens aligned with a hole in the center of the display. The camera is focused on participants' face and is used to record their eye-movements, which are later coded using frame by frame viewing on a digital VCR.

There are several advantages to this method. First, we have found that more preschools, parents, and children are willing to participate in research that uses familiar and noninvasive technology. Second, the hidden camera technique is far less expensive than eye-tracking making it

accessible to more researchers. All that is needed is a laptop computer with speakers, a small camera, a stage for displaying props, and some method for coding videotape frame by frame (e.g., an editing deck with a jog-shuttle knob or a computerized coding system). Since most of this equipment is already present in the typical language acquisition lab, the paradigm can be easily adopted by experimenters who are just beginning to explore online methods. Third, the equipment is light, compact and very easy to set up, thus the paradigm does not require a dedicated testing room and can be readily transported to schools or distant populations. Finally the poor man's eyetracker avoids some of the technical limitations of other eye-tracking methods. Because of their weight and fragility, head-mounted eye-trackers are not suitable for children under about four and a half. Table-mounted eye-trackers can be used with children of any age. However, most current models have difficulty tracking gaze if the child's head is in motion. Consequently, they are ill-suited for use during act out tasks and with children who have difficulty sitting still.

Although new to sentence processing, the poor man's eyetracker is simply a variant of the preferential looking paradigms which are widely applied in developmental psychology (Fantz, 1961; Fagan, 1970; Spelke, 1979). Intermodal preferential looking studies typically show very high inter-coder reliability especially when frame-by-frame coding is employed (Hirsh-Pasek & Golinkoff, 1996). Many of these intermodal studies have

looked at children's comprehension of spoken language (Hirsh-Pasek & Golinkoff, 1996). When frame-by-frame coding is synchronized with a speech stimulus, the paradigm is quite similar to the eye-tracking paradigms used in sentence processing. These techniques have proven to be sensitive enough to explore the resolution of pronouns in preschoolers (Song & Fisher, 2002) and improvements in the speed of word identification between 15 and 24 months (Swingley, Pinto & Fernald, 1999).

In our lab we record and code eye-movements using DVcam equipment and tape stock. Unlike most formats DVcam has audio-lock recording which ensures that the audio and video tracks remained synchronized. Coding is completed in two steps. The first coder listens to the tape with the audio on and notes the time of the onset and offset of the sentence. These time points are used to define the period during which the eye-movements will be coded and to synchronize the eye-movement data to the speech stream during analysis. A second coder views the tape with the audio off and notes the onset of each change in gaze and the direction of the subsequent fixation. The direction of a fixation is coded as being in one of the quadrants, at center, or away from the display. If the participant's eyes are closed or not visible, the frame is coded as missing and the data are excluded from the analysis. A subset of the tapes is

independently coded by an additional observer and intercoder reliability is generally high (> 90% in the studies presented below).

To validate this method, Snedeker and Trueswell (2004) performed a direct comparison of data collected with the hidden camera and data collected with a head-mounted eye-tracking system. They found that the two methods were quite comparable: they converged on the same fixation location for 93% of the video frames and produced similar amounts of lost data (2-3% of frames). Several aspects of our procedure may be critical to achieving this level of accuracy. First, the room is well lit and the camera is tightly focused on the participant's face, allowing the coders to see the iris and thus determine eye position. Second, subjects are placed close to the display and their chair is positioned so that their gaze is centered at the location of the camera. This ensures that gazes to each of the four quadrants can typically be distinguished by the direction in which the eyes rotate and not merely by the extent to which they do so. The image of the participant's face on the hidden camera is monitored throughout the experiment to ensure that the subject remains properly positioned. Finally, to ensure that coders receive frequent feedback about the relation between eye position and gaze direction, we elicit a predictable sequence of gazes from the participants at the beginning of each trial by laying out the props in a consistent order (clockwise from the upper left) and drawing their attention to each one.

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Insert Figure 1 about here  
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### 3.2 *Stimuli*

In these studies we examine structural priming in sentences with dative verbs. Dative verbs, such as *give*, *bring*, or *send*, typically appear with three arguments: an agent, a recipient, and a theme. In English there are two ways in which these arguments can be expressed (see 3). In the prepositional object construction (PO, 3a) the theme appears as the direct object while the recipient is expressed by the prepositional phrase marked by *to*. In the double object construction (DO, 3b) the recipient is the direct object while the theme is expressed as a second noun phrase and no preposition is used.

- (3) a. The misanthrope left his entire fortune to Shamu.  
b. The misanthrope left Shamu his entire fortune.

Datives are well-suited to our purposes for three reasons. First, they appear to be acquired quite early; children comprehend and produce both forms by age three (Campbell & Tomasello, 2001; Gropen, Pinker, Hollander, Goldberg & Wilson, 1989). Second, the two 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. Finally, datives are commonly used in studies of production priming in adults, facilitating comparisons across experiments.

Each experimental block consisted of: 1) some filler sentences (which were not datives); 2) two prime sentences that were either DO or PO datives (e.g., DO: *Give the lion the ball*; PO: *Give the ball to the lion*); and 3) a final target sentence, which was also a DO or PO dative (e.g., DO: *Bring the monkey the hat*; PO: *Bring the money to the bear*). In all of our studies prime type and target type were fully crossed and manipulated between subjects, resulting in four possible conditions (DO prime-DO target; DO prime-PO target; PO prime-DO target; PO prime-PO target). Each participant in a given study was randomly assigned to one of these conditions.

Our goal was to determine whether DO and PO datives would prime the interpretation of subsequent utterances that used a different verb and had no common content words. To link this priming to eye-movements we made use of a well-studied phenomenon in word recognition, the cohort effect (Marslen-Wilson & Welsh, 1978). As a spoken word unfolds, listeners activate the lexical items that share

phonological features with the portion of the word that they have heard. In the visual world paradigm, this process results in fixations to the referents of words that share features with the target word (Allopenna et al., 1999). These effects are particularly strong at the beginning of a word, when all of the phonological information is consistent with multiple words (the members of this cohort). In our studies we used priming as a top-down constraint which might modulate the activation of different members of a phonological cohort.

On target trials, the set of toys that accompanied the utterance contained two items that were phonological matches to the *initial* part of the direct object noun (see Figure 1). One was animate and hence a potential recipient (e.g., a monkey) while the other was inanimate and hence a more likely theme (e.g., money). Thus the overlap in word onsets (e.g., *mon...*) created a lexical ambiguity which was tightly linked to a short-lived ambiguity in the argument structure of the verb. We expected that priming of the DO dative would lead the participants to interpret the first noun as a recipient, resulting in more looks to the animate match, while priming of the PO dative structure would lead them to interpret it as a theme resulting in more looks to the inanimate match. The instructions were prerecorded by a speaker who used an enthusiastic tone and slow delivery.

### 3.3 *Selecting a dependent variable*

Dependent measures that are commonly used in eye-tracking studies include first gaze duration, latency 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, Thorpe, Hurtado & Williams, 2006). Therefore, we did not calculate first gaze duration or latency, and analyzed total fixation time only. We will refer to total fixation time simply as *looks*. In most of these studies 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., *mon...*). Within this interval, we were interested in looks to the potential animate recipient (e.g., monkey) and the potential inanimate theme (e.g., money). 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 explored 3 different dependent measures: 1) looks to the animal as a proportion of all looks; 2) looks to the object as proportion of all looks; and 3) the difference between 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 significant effects for one of the measures but not the others. In our pilot studies we found that analyses of the *dispreferred* item appeared to be more sensitive to priming effects. For example, if participants preferred to look at the animal irrespective of the experimental condition, then we would find reliable effects of priming in our analysis of looks to the object, which was the dispreferred item, but not in our analysis of looks to the animal. Therefore, our primary measure in the studies that follow will be looks to the dispreferred item.

#### **4 Verifying Syntactic Priming in Adult Comprehension**

There was, unfortunately, one road block to using comprehension priming to explore the development of structural generalizations. The existence of this form of priming is controversial in adults, raising the possibility that priming paradigms are insensitive to structural representations in comprehension, or that abstract syntax plays a weaker role in comprehension than production (Townsend & Bever, 2001). Critically, while several prior studies have explored structural priming during comprehension, none of them provide unambiguous evidence for

abstract syntactic priming for the kinds of sentences that we intended to explore (post-verbal ambiguities in argument structure). Two of the studies that found robust priming effects (Luka & Barsalou, 2005; Noppeney & Price, 2004) used structures which were not semantically equivalent (e.g., relative clause attachment ambiguities), leaving open the possibility that the priming effects were semantic rather than syntactic. In addition, these studies used measures with a coarse temporal grain, creating uncertainty about whether the effects are due to initial structural analysis or later reanalysis. Two recent eye-tracking studies have searched for evidence of priming during online comprehension. Scheepers & Crocker (2004) studied the processing of German transitive sentences with case-marking. They found that the online interpretation of ambiguously marked preverbal arguments was influenced by prior unambiguously marked prime sentences. In contrast, using the English dative alternation, Arai, Van Gompel and Scheepers (2007) looked for priming of the interpretation of post-verbal arguments. They found priming when prime and target sentences contained the same verb, but not when they contained different verbs (see also Branigan, Pickering & McLean, 2005).

Thus, while there is robust evidence for verb-specific priming during comprehension the scope and status of abstract priming is uncertain. Our first experiment revisited the role of abstract structural

information during adult language comprehension. We tested 28 undergraduates in a between-verb priming task. In this study, we used a priming paradigm in which each sentence was acted out (act-out priming task, hereafter). Each participant heard four blocks of instructions. In each block, the first two sentences were fillers (non-datives), the next two were DO or PO prime dative sentences and the last was a target DO or PO dative sentence containing a temporary ambiguity (e.g., money/monkey). For every sentence, new toys were put out, a sound file with an instruction was played, and the participant carried out the command. Thus from the participant's perspective there was no obvious difference between the filler, prime or target trials. *Hand*, *pass*, *feed* and *send* were each used in two prime sentences in two different blocks. *Throw* and *show* were each used in two target sentences.

Unsurprisingly, these adults performed the right action on all target trials, indicating that they were able to interpret the utterance irrespective of the prime type. However, their eye movements during the period of ambiguity were clearly affected by the prime. Since there was a weak preference for looks to the animal, our primary analysis focused on looks to the object (Figure 2a). Participants who had heard PO primes were more likely to look at the object (the potential theme) than those who had heard DO primes. There were no reliable effects of prime type on looks to the animal (the preferred item). The effect of prime type persisted in the

analyses of the difference scores. While participants who had heard DO primes clearly preferred the animal (the potential recipient), those who had heard the PO primes had a weak preference for the object.

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Insert Figure 2 about here

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Because the prime and target sentences in this experiment used different verbs and nouns, these results suggest that abstract representations are used during online language comprehension. Thus they contrast strongly with the results of Arai, Van Gompel and Scheppers (2007) who found no between-verb comprehension priming for datives. That study used a passive viewing task, while our task required participants to plan and execute an action. Thus we considered the possibility that the locus of our priming effect was in the mapping from the utterance to the action plan. We explored this by testing whether abstract priming persists when prime sentences are not enacted or mapped onto a visual array. If priming persists under these conditions we can rule out the possibility that actions are critical to producing priming during comprehension.

Participants passively listened to a story that contained the prime sentences and then acted out a target sentence using a set of props (story priming task, hereafter). Specifically, the participants were told that they

were going to listen to two voices (Bob and Susan) which would be presented on a computer. Bob would tell stories, while Susan would give them instructions to act out. At the beginning of each trial, Bob's voice talked about events that happened in a children's store the day before. Susan's voice then interrupted with "*It's my turn. Are you ready?*" followed by the actual instruction. The first three trials were practice items that did not involve datives, while the subsequent trials alternated between critical trials and filler trials. On critical trials, Bob's last two sentences were DO or PO dative primes, while Susan's target instruction was also a DO or PO dative. There were a total of 6 critical trials with *read, teach, sing, show, sell* and *feed* as the prime verbs and *bring, pass, throw, send, toss* and *hand* as the target verbs. As Figure 2 illustrates, the effects of priming persisted in the story priming task, demonstrating that priming occurs even when the prime utterance is not mapped to an action or a visual display. Again there was a weak preference for looks to the animal and so our analyses focused on looks to the object. Participants who had heard PO primes were more likely to look at the object than those who had heard DO primes.

The two experiments reported here demonstrate comprehension-to-comprehension priming in adults when different verbs are used in prime and target sentences. These studies extend the findings of the prior comprehension studies in several ways. First, they demonstrate that

priming occurs even when semantically equivalent dative sentences are used, thus minimizing the possibility that the effects are semantic rather than syntactic. Second, they show that priming unfolds soon after the onset of the first noun, which was on average less than 550 ms after verb-onset. This suggests that priming influences initial syntactic analyses. In addition, these results complement Scheepers & Crocker (2004) by showing priming during the interpretation of post-verbal arguments. Abstract, non-verb-specific information appears to influence comprehension even after a specific verb has been encountered.

We attribute the divergence between our findings and those of Arai, Van Gompel and Scheepers (2007) to two differences between the studies. First, Arai and colleagues used a single prime before each target trial while we used two. Previous evidence suggests that encountering multiple verbs in a structure leads to stronger structural priming (Pickering & Branigan, 1998; Savage et al., 2006). Second, Arai and colleagues presented the target sentence immediately after the prime with no intervening verbal materials, resulting in a lag of approximately 1200 ms between prime and target trials. The lag in our studies was considerably longer, in terms of both intervening utterances and elapsed time (approximately 5 sentences and 30-60 seconds for the act-out task and 2 sentences and 4-5 seconds for the story priming task). A recent study by Konopka and Bock (2005) suggests that the distance between the prime

and the target affects the relative magnitude of lexically-specific priming and abstract priming. They found lexically-specific priming only when the target immediately followed the prime. In contrast, abstract priming was numerically greater when a single sentence intervened between the target and prime (priming at lag 1 > priming at lag 0) and remained robust across as many as 3 intervening sentences. Konopka and Bock attribute lexically-specific priming to an explicit memory for the prime sentence which decays rapidly. Abstract priming, they argue, involves a form of implicit learning, parallel to the setting of connection weights in a neural network (Chang, Dell & Bock, 2006). Extending this proposal to comprehension priming generates the prediction that abstract priming would be greater in the present experiments while lexically-specific priming would be greater in the study by Arai and colleagues. Systematic investigation of the effect of the prime-to-target lag on comprehension priming will be required to validate this speculative account.

## **5 Syntactic Priming in Preschoolers**

Armed with a paradigm that was sensitive to abstract structural priming in adults, we set out to discover whether the same paradigm could be applied to children. We focused our work on two age groups: young four-year-olds and young three-year-olds. Young four-year-olds were of interest

because they have failed to show abstract priming effects in two production priming studies (Savage et al., 2003, Gamez et al., 2005) despite showing fairly robust generalization in novel-verb production tasks (Tomasello, 2000).. This raises the possibility that generalization paradigms may not reflect the structure that underlies everyday language use (Ninio, 2005). Young three-year-olds were of interest because they typically fail to generalize in novel verb production studies (Tomasello, 2000). Thus evidence of abstract priming in this age group would challenge the empirical basis of the verb island hypothesis.

Of course, one cannot simultaneously test the sensitivity of a method and the existence of the phenomena that it is supposed to be sensitive to. Failure to find parallel effects of abstract structural priming in young children could indicate either that the task is not appropriate to explore priming in this age group, or that children fail to employ abstract representations in online comprehension. Thus we began by testing our task on an uncontroversial phenomenon: within-verb priming in four-year-olds. Within-verb priming can be mediated by abstract structure or lexically-specific representations. Given the results of the prior production priming studies and the novel-verb generalization studies we would expect to find robust priming within verbs in any task that is sensitive to priming of the relevant representations.

### 5.1 Experiments with four-year-olds

Twenty young four-year-olds ( $M = 4;1$ ) participated in an act-out priming task, similar to the one we conducted with adults. All prime and all target sentences used the verb *give*, which is the most frequent dative verb in the input to children and in speech between adults. The temporary ambiguity in each target sentence was created by using an animal as the recipient in the DO sentences and a compound noun beginning with the same word as the theme in the PO sentences (e.g., DO: *Give the bird the dog bone*; PO: *Give the birdhouse to the sheep*), resulting in a long ambiguous region (400 ms).

The children performed the right action on 89% of the target trials. Two-thirds of the errors were role reversals (e.g., giving the bird *to* the dog bone in response to *Give the bird the dog bone*). Most of these 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 the prime sentences. Across conditions, children looked at the animal more than the object, thus our analysis focused on looks to the object (Figure 3a). Those children primed with PO sentences (where the first noun is the inanimate theme) looked more at the object than those primed with DO sentences (where the first noun is the animate recipient). Thus we found that four-year-old children's interpretation of temporarily ambiguous

dative sentences was rapidly influenced by the previous sentences that they heard. Because we used the same verb in both prime and target sentences, this effect could reflect either verb-specific or abstract priming.

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Insert Figure 3 about here

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To explore whether four-year-olds have structural representations that are broader than individual verbs, we conducted a parallel study of across-verb priming. The prime sentences used *show* and *bring*, while the targets were the same as those used in the within verb priming study, and thus used the verb *give*. Thirty-eight young four-year-olds participated ( $M = 4;0$ ). The children performed the correct action on 90% of the target trials. Our analysis of looks to the dispreferred item (the object) revealed a significant effect of prime (Figure 3b). As predicted, those primed with PO sentences looked more at the object than those primed with DO sentences. Thus 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. This priming across verbs demonstrates that four-year-olds have structural representations of dative utterances that are not bound to individual verbs.

There are however, two limitations to this finding. First while these results clearly demonstrate between-verb priming for the target verb *give*,

they cannot tell us whether this priming occurs across a wider range of dative verbs. The verb *give* is unique: it is the most frequent dative verb in the input and under some theories it has a privileged role in the acquisition of dative constructions (Goldberg, 1995; Ninio, 1999). Second, although the findings of the production priming tasks have been mixed, most theorists would agree that four-year-olds demonstrate some degree of abstract structural generalization in novel verb production tasks. Much of the debate about the nature of children's representations has centered on three-year-olds. Thus it was imperative to extend these findings to younger children and to a wider variety of dative verbs.

## 5.2 *Experiments with three-year-olds*

To validate our technique with a younger age group we began by exploring within-verb priming using the act-out priming task. Thirty young three-year-olds ( $M = 3;1$ ) participated. Each child heard one of two lists each containing 4 different dative verbs, but within a given block, the prime and the target verbs were the same. The verbs were *pass*, *send*, *throw* and *bring* for group 1 and *hand*, *show*, *toss* and *take* for group 2. The phonological ambiguities in target sentences did not depend upon compound nouns, because we were unsure whether three-year-olds would know them. Instead we used animal/object name pairs that overlapped in

their onsets (e.g., DO: *Show the **horse** the book*; PO: *Show the **horn** to the dog*).

Because the three-year-olds were slower and more variable in their eye movements than the four-year-olds, we averaged looking time over a longer time window in our analyses. While minimum saccade latencies can be as small as 133 ms for adults in a simple visual task (Matin, Shao & Boff, 1993), 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 are likely to be higher. For example, Swingley, Pinto and Fernald (1999) found mean latencies of 558 ms 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 983 ms for the three-year-olds (SD = 292 ms) and 437 ms for the four-year-olds (SD = 188 ms). Therefore, our analyses for three-year-olds began 200 ms after the onset of the first noun but (conservatively) extended up to 2 seconds after noun onset. Because this window is likely to include looks that were programmed after the first noun was disambiguated, we might expect to see an effect of target type in addition to any prime effects.

Children performed the correct action on 79% of the target trials. Most errors (72%) were due to children not acting out DO sentences (picking up the toys but not carrying out the action). Across conditions,

children showed a slight preference for the object over the animal. Our analysis of looks to the dispreferred item (the animal) found a significant effect of prime (Figure 4a). As predicted, those primed with DO sentences looked more at the animal. Unsurprisingly, there was also a significant effect of target, reflecting the disambiguation of the direct object during this time window. In addition there was a marginal interaction between prime and target, suggesting that the priming effect was stronger for DO target sentences.

The error rate in three-year-olds was considerably higher than in four-year-olds. Because eye movements on error trials are hard to interpret, we performed a secondary analysis excluding those trials where there was an error in the action. The effect of prime type on looks to the dispreferred item (the animal) persisted in this analysis. Thus we found within-verb priming in three-year-old children using eight different dative verbs. Those primed with DO sentences looked relatively more at the animal than those primed with PO sentences. These results demonstrate that priming is not restricted to frequent, prototypical dative verbs such as *give*.

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Insert Figure 4 about here  
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Because this within-verb priming could arise from either verb-specific or more abstract representations, our next experiment examined between-verb priming in this population. Thirty-two young three-year-olds ( $M = 3;1$ ) participated. Each child was assigned to one of two stimulus lists. In one list *pass*, *send*, *throw* and *bring* appeared as targets while *hand*, *show*, *toss* and *take* appeared as primes. In the second list, the role of the verbs was reversed. Thus the target and prime sentences were the same as those in the within-verb priming study but they were simply paired differently across participants. The two prime sentences in each block used two different verbs because varied primes have been found to lead to greater production priming in older children (Savage et al., 2006).

Children performed the right action on 75% of the target trials. Our analysis of looks to the dispreferred item (the animal) found a significant effect of prime only. As predicted, those primed with DO sentences looked more at the animal (Figure 4b). In a secondary analysis we excluded all trials where children committed errors. The effect of prime on looks to the animal persisted. Thus we found 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 and *give* did not appear as a prime or target.

The results reported here demonstrate within- and across-verb priming in both three- and four-year-old children. 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. This priming appears across a variety of verbs and in an age group that shows limited productivity in many novel verb generalization tasks (see Tomasello, 2000).

## **6 Identifying the Locus of Priming Effects in Children**

What is the source of this priming effect? Our methodology rules out an alternate explanation for previous production-priming results found in children. Because the alternate constructions used in the child priming studies are distinguished by the presence or absence of closed-class words or morphemes (*to* for datives or *by* and the participle for passives), production effects could reflect the priming of these words rather than grammatical structures. We avoided this possibility by measuring priming of the role assigned to 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 DO- and PO-prime conditions begin to emerge prior to the onset of this morpheme.

Nevertheless, several alternate explanations of these priming effects remain. The first, and the least interesting, invokes no representation of the phrase structure of the utterance or the argument structure of the verb. Perhaps children in the DO prime conditions simply formed the expectation that the animal would be mentioned first while children in the PO prime conditions learned to expect that the object would be mentioned first. The remaining hypotheses all invoke syntax in one way or another.

The simplest of these hypotheses is that our manipulation directly primed the syntactic structures used in double object (V NP NP) and prepositional (V NP PP) datives (Pickering & Branigan, 1998). These structures 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, DO primes would potentiate the recipient $\leftrightarrow$ direct object mapping, while PO primes would potentiate a theme $\leftrightarrow$ direct object mapping. Since the recipient and theme roles are in turn correlated with animacy (the recipient is usually animate, theme is usually inanimate), this would give rise to the pattern of eye movements seen in our experiments. Alternatively, direct

mappings between animacy features and syntactic positions (e.g., animate $\leftrightarrow$ direct object or inanimate $\leftrightarrow$ direct object) may have been primed. 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, Bock & Goldberg, 2003).

To disentangle these different possibilities we will have to examine a broader range of prime and target types to determine which of these features must overlap for robust structural priming. We have begun exploring this issue with the story priming task. This task has the advantage of allowing us to use prime sentences that are not commands and cannot be acted out. Our current work examines the effects of 4 kinds of primes (4a-d) on the interpretation of DO and PO datives. To date, thirty-two four-year-olds (8 per prime type) have participated in this study of the nature of between-verb priming.

- (4) a. DO prime: She read the girl a story.
- b. PO prime: She read a story to the girl.
- c. Intransitive prime: She winked.
- d. Locative preposition prime: She carried the girl to the bed.

The preliminary results are promising (Figure 5).

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Insert Figure 5 about here  
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The observed pattern for the DO and PO primes replicates and extends the results of the act-out priming task. Subjects who hear DO-primes show a strong preference for the animal during the region of ambiguity, while those who hear PO-primes have no strong preference for either the animal or the object. Thus dative priming in children persists even when prime sentences are not mapped to an array or an action, and when the prime and target sentences differ along several syntactic and semantic dimensions (e.g., primes in the present study have subjects, include indefinite NPs and in many cases abstract themes).

The intransitive priming condition serves as a control. In her production studies, Bock noted that intransitive primes resulted in production patterns that were midway between DO and PO primes (1986). We find a parallel pattern in our data. During the ambiguous region of the dative sentences, the eye-movements of participants who received intransitive primes are intermediate between the two types of dative primes. This suggests that structural priming is not limited to one of the two dative forms.

Finally the locative preposition primes offer a preliminary answer to our questions about the nature of these priming effects. These

utterances have the same mapping between animacy and position as the DO datives (animate $\leftrightarrow$ direct object and inanimate $\leftrightarrow$ second NP). However, they have the same syntactic structure as the PO datives (NP PP) and a similar pattern of thematic role assignments (theme, goal/recipient). In this condition the looks during the ambiguous region clearly pattern with the PO primes: the locative prime increases looks to the object relative to the intransitive control resulting in a difference score that is reliably smaller than the DO primes but indistinguishable from the PO primes (see Bock & Loebell, 1990 for parallel findings in adult production priming). Thus we tentatively conclude that comprehension priming of datives in preschoolers is not linked to animacy features but may be attributable to the priming of syntactic frames or patterns of thematic role assignment.

## **7 Conclusions**

### *7.1 Comparison to Previous Studies*

Our results add to the existing literature in several ways. First they provide converging evidence that young children have abstract structural representations. Our findings complement those of novel verb comprehension studies. Those studies show that children can generalize

attested structures to a new verb in the absence of lexically-specific evidence for this structures. In contrast, our data demonstrate that children use abstract representations in a situation where they know the verbs and could presumably rely solely on lexically-specific representations, were this their dominant form of grammatical representation. Second, these studies demonstrate that these abstractions are active in children during online comprehension. Finally, these findings add to the nascent literature on structural priming in preschoolers. Our methodology rules out some alternate explanations for production-priming (e.g., priming of closed class items), and our results show that abstract structural priming is not restricted to production as suggested by some (Arai et al., 2007).

But how can we reconcile these findings with the results of novel verb production studies? 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 produce the across-verb comprehension priming reported here. We see two reasons to be skeptical of this analysis. First, the pattern of data that we observed

provides no evidence for a developmental shift in the relative strength of lexical and abstract representations. As we discuss below, our paradigm allows us to estimate the relative size of abstract priming and lexically-specific priming. In both age groups we find robust evidence for abstract priming in the form of reliable between-verb priming but no reliable evidence of lexically-specific priming (i.e., no interaction between prime type and within/between verb priming in either age group). In fact, the evidence for lexically-specific priming is particularly weak in the three-year-olds, where the difference in effect size between the within and between verb priming is negligible. Second, the graded strength hypothesis is weakened by a recent study demonstrating that three-year-olds can generalize the dative alternation in a novel-verb *production* task (Conwell & Demuth, 2007). Thus, by 3 years of age, some abstract representations are clearly strong enough to influence both comprehension, and production, suggesting the need for an alternate explanation of the co-existence of item-specific use and abstract structural representations. Below, we describe how structural priming can be used to investigate one such alternate explanation which has been widely accepted in the adult sentence processing field.

## 7.2 *Using Structural Priming to Investigate Children's Representations*

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, Levin, 1993; Jackendoff, 2002). Developmentally, there is a tension between evidence for early abstract representations (e.g., Fisher, 2002b) and item-specific use (e.g., Tomasello, 2000). Studying the relation between children's lexical representations and their 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 & Kim (1998) found that reading times for temporarily ambiguous sentence complements like (5) were affected by brief exposures (39 ms) to one-word primes.

(5) 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. Note that 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, the authors accounted for these findings by positing that individual verbs are associated with abstract structural representations which can be primed (see e.g., MacDonald, Pearlmutter & Seidenberg, 1994). The strength of the link between the verb and a structural node depends on learner's prior exposure to that particular verb in that particular syntactic context.

Models of this kind provide an explanation for the co-existence of generalization and item-specificity in young children (see Fisher, 2002b). Perhaps young children have the same linguistic architecture as adults, but simply lack experience. Perhaps like adults, they have abstract syntactic representations, abstract semantic representations, and mappings between the two. However, because their experience with individual verbs is limited the connections between some individual verbs and some structures may be weaker or even absent. Were this true, we would expect children to succeed when knowledge of the construction alone is sufficient to solve the problem. This is generally the case in novel verb preferential

looking studies. The structure is provided and the use of general linking rules is sufficient to interpret the utterance without integrating verb specific information. However, when the task requires children to use the connection between the verb and the structure, we would expect that performance would depend upon 1) the child's prior experience with the verb in that structure; 2) their experience of the verb in alternate structures. 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. Known verb priming studies allow the child to make use of previously acquired associations between specific verbs and abstract structures.

Similar models have been invoked to explain the differences between within- and across-verb priming in production studies. As we noted above, while structural priming occurs even when utterances share no content words, some researchers have found that priming is greater when the same verb is used in both sentences (Pickering & Branigan, 1998). Pickering and Branigan explain this pattern with a theory in which individual verbs are linked to abstract combinatorial representations such as [NP, NP] and [NP, PP]. 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 in three- and four-year-old children. For three-year-olds, the effect sizes for within- and across-verb priming were  $\eta^2 = .21$  and  $\eta^2 = .17$  respectively. For four-year-olds, the within-verb and across-verb priming effect sizes were  $\eta^2 = .45$  and  $\eta^2 = .16$  respectively. Thus, for both age groups within-verb priming appears to be stronger than across-verb priming. However, the interaction between the two types of priming was not significant for either group.

### 7.3 *Final Words*

The studies presented in this chapter demonstrate that the online interpretation of dative utterances can be structurally primed by prior comprehension of other dative sentences. This priming effect is robustly present in adults, four-year-olds and three-year-olds and appears regardless of whether the prime sentence is acted out or mapped onto a visual display. These effects are not, or not solely, lexically-specific. They persist when different verbs and nouns are used in the prime and target sentences. The between-verb priming effect demonstrates that children as

young as 3 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?). Critically, 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.

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Figure 1. Example of a scene as viewed by the participant. Eye movements were recorded by a camera placed behind the hole in the center. DO sentence: *Bring the **monkey** the hat*; PO: *Bring the **money** to the bear*. (The ambiguous interval is in bold.)

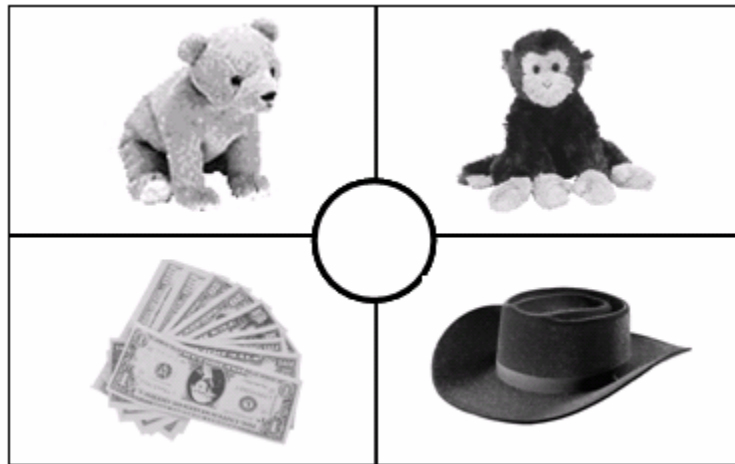


Figure. 2. Structural priming effects during comprehension in adults:  
Proportion of looks to the inanimate match (consistent with PO priming)  
in the act-out priming task (left panel) and the story priming task (right  
panel).

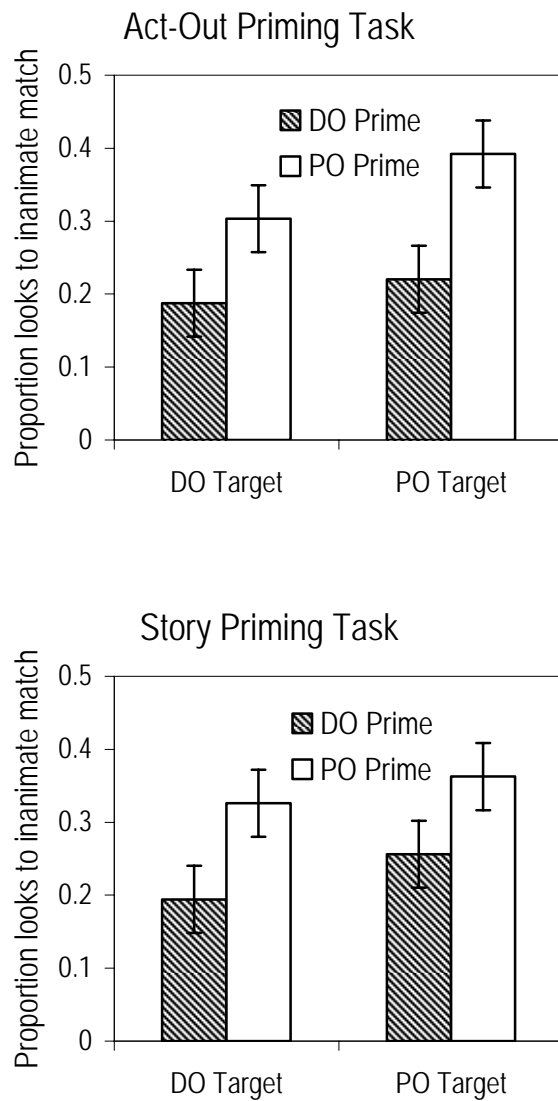


Figure. 3. Structural priming effects in 4 year olds: Proportion of looks to the inanimate match (consistent with PO priming) in the within-verb priming condition (left panel) and the between-verb priming condition (right panel).

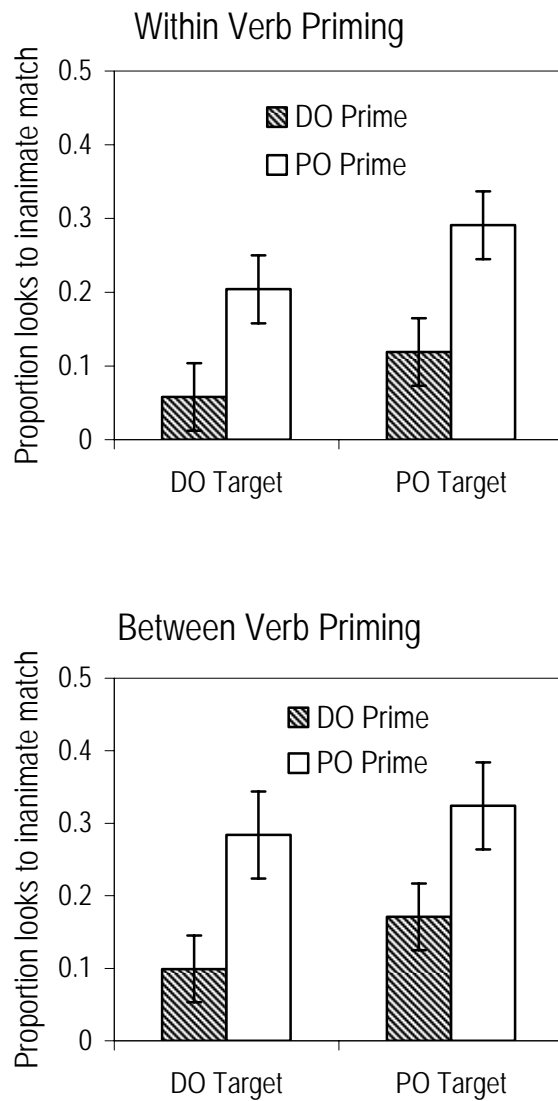


Figure. 4. Structural priming effects in 3 year olds: Proportion of looks to the animate match (consistent with DO priming) in the within verb priming condition (left panel) and the between verb priming condition (right panel).

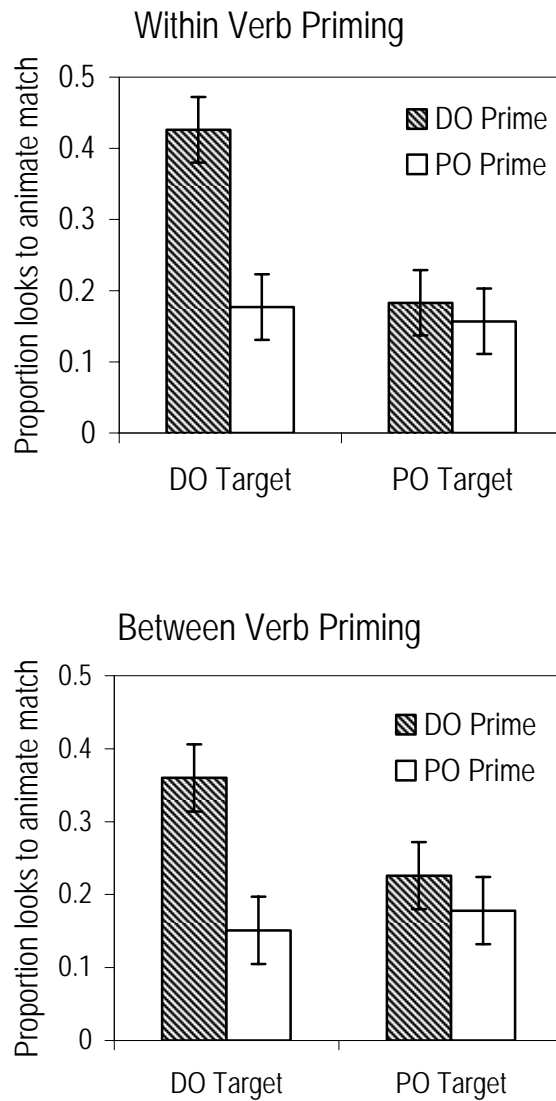
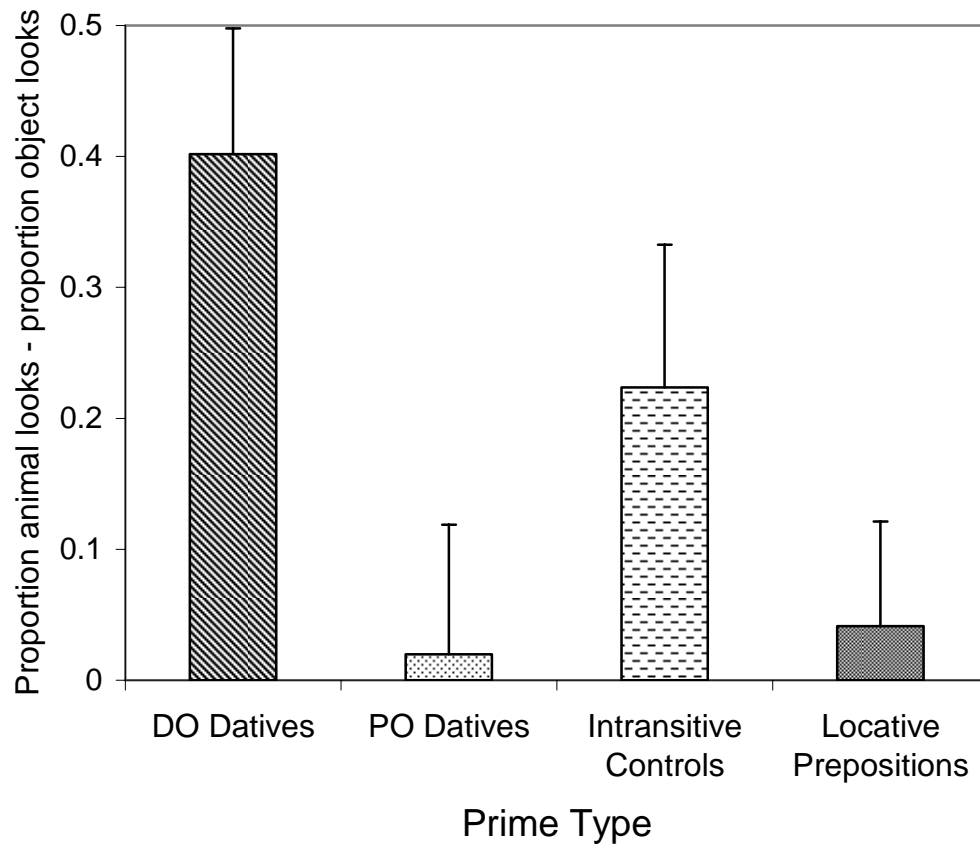


Figure 5: Story priming task with 4 year olds. Effects of four prime types on the interpretation of dative sentences (PO and DO targets collapsed) as measured by the difference between the proportion of looks to the animate match and the proportion of looks to the inanimate match (higher values are consistent with DO priming).



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<sup>1</sup> The confederate dialog task used by Branigan and colleagues (2005) may tap different mechanisms than the picture description tasks described above. In adults, priming effects in dialog paradigms appear to reflect higher-level processes facilitating coordination during dialog, in addition to lower-level structural priming (Branigan et al., 2000; Pickering & Garrod, 2004). The task used in the Branigan child study may have promoted direct comparison of the prime and target utterances, further encouraging parallelism. On every trial the experimenter and child each put down a card with a colored object on it, the experimenter described her card (e.g., “the red cat” or the “the cat that is red”), the child described his, and then both participants raced to pick up the cards if they matched. The priming effects were larger than those observed in parallel studies with adults and prior studies with children (82% matches to the prime in the absence of lexical overlap).