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Citation

Tothathiri, Malathi and Jesse Snedeker. 2010. The role of thematic roles in sentence processing: evidence from structural priming in young children. Harvard University Department of Psychology.

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The Role of Thematic Roles in Sentence Processing: Evidence from Structural Priming in Young
Children

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Abstract

The syntactic realization of a verb's arguments is constrained by the role that the argument plays in the meaning of the verb. In most linguistic frameworks, these constraints are captured by mappings between syntactic functions and thematic roles. Such mappings clearly shape our interpretation of novel verbs. But there is controversy about when these mappings develop and whether they are employed in the processing of utterances containing known verbs. We explored these issues using the visual-world paradigm and structural priming during comprehension in 4-year-old children. In Experiment I, we found robust priming of dative constructions. This priming persisted when animacy cues were put in competition with argument structure, indicating that the locus of priming was either in syntax or in the mapping between thematic roles and syntactic functions. Experiment II demonstrated priming from locatives to datives indicating that this priming was not purely syntactic. Together these experiments provide evidence for the use of thematic mappings during sentence processing, independent of confounding syntactic or conceptual factors. We discuss the developmental implications, apparent discrepancies with the adult priming literature, and the compatibility of our findings with different theories of argument structure alternations.

Keywords: thematic roles; structural priming; syntactic priming; eye-tracking; comprehension; children; locative alternation; dative alternation

Introduction

Natural languages are characterized by systematic but complex correspondences between a verb's semantics and the syntactic realization of its arguments (Baker, 1988; Dowty, 1991; Fillmore, 1968; Fisher, Gleitman & Gleitman, 1991; Jackendoff, 1990; Levin, 1993; see Levin & Rappaport Hovav, 2005 for review). While theoretical approaches to argument realization vary considerably, all accounts must explain the robust generalizations that exist within and between languages. For example, verbs that encode a change of state can appear either as transitives or intransitives (1a-b). However, in the intransitive form the subject must be the transformed entity, while in the transitive form the subject must be the entity that caused the change, ruling out utterances like 1c.

1a. The security officer sank/burned/exploded/opened/froze the unattended suitcase.

1b. The unattended suitcase sank/burned/exploded/opened/froze.

1c. *The unattended suitcase sank/burnt/exploded/opened/froze the security officer.

(*where the suitcase is the transformed entity*).

Since Fillmore's 1968 paper "The Case for Case" researchers working in a variety of grammatical frameworks have used the notion of thematic roles to understand these phenomena. Theories of this kind share two features. First, they posit that the different roles that participants play in an event can be categorized into a limited number of types (thematic roles). Second, they posit a set of rules that map these roles onto different syntactic positions or functions. For example, Fillmore (1968) proposed a thematic hierarchy for subject assignment in which causal agents (like *the security officer*) outrank themes (like *the unattended suitcase*). The highest ranking argument that is expressed becomes the subject, ruling out utterances like (1c) but allowing for utterances like (1a) and (1b). Other theorists account for the same pattern by

positing a one-to-one mapping between thematic roles and initial syntactic positions (agents are subjects, patients are objects), followed by mandatory movement to ensure that a surface subject is present in the case of the intransitive (e.g., Baker, 1988).

In contemporary theories of argument realization, thematic roles are rarely treated as theoretical primitives. Instead they are seen as emergent constructs defined by the semantic structures in which they are embedded (see Levin & Rappaport Hovav, 2005). Typically these theories propose that verbs can be decomposed into primitive predicates. For example, Rappaport Hovav and Levin (1998) suggest that transitive change of state events (like 1a) have the semantic structure in 2.

2. [[X ACT] CAUSE [Y BECOME < OPEN>]]

The argument highest in the semantic structure typically appears as the subject while the lowest argument (the first one to compose with the verb) appears as the direct object (Levin & Rappaport Hovav, 2005). While this decompositional approach has additional explanatory power, it preserves many of the insights of thematic role lists, largely because of the tight correspondence between thematic roles and the arguments of primitive predicates. For example, under many theories an agent is defined as an argument (or second-order argument) of the predicate CAUSE, a patient is an argument of BECOME, and a theme is an argument of GO (see e.g., Jackendoff, 1990). Thus, for ease of exposition we will continue to discuss the syntax-semantics interface in terms of thematic roles.

Thematic roles in young children

Constraints on thematic mappings clearly have some explanatory power in accounting for within- and across-language patterns of argument realization. However, there is considerable dispute about the nature and origin of these constraints. To what degree are they universal? Do

they reflect the relative cognitive salience of different roles or are the mappings driven by language-internal concerns? What role does lexical knowledge play in argument realization? Understanding the ontogeny of thematic mappings may provide insight into these questions.

An obvious way to explore children's acquisition of argument structure is to examine whether young children produce utterances that respect the argument realization constraints of their language. The finding, broadly speaking, is that they do. From the time children begin to combine words, their utterances respect the word order and thematic mapping patterns of the target language. For example, young children acquiring English put agents before the verb and patients after it. But as many have noted, this precocious propriety does not necessarily indicate that toddlers possess broad rules linking thematic roles and syntactic positions. Other representations could suffice. For example, a child who relied on simple mappings between the conceptual features of entities and syntactic positions (animate → subject, inanimate → object) would rarely be wrong (Slobin, 1981). Another possibility, suggested by Tomasello (1992), is that children's early production is governed by generalizations that are specific to individual predicates. On this proposal, children learn each verb independently, discovering the specific semantic relations that are attributed to each argument and their morphosyntactic realizations (the tickler goes before *tickle*, the ticklee after it). Thus it is proposed that at an early stage of acquisition there are no verb-general thematic roles, no abstract syntactic functions, and no principles of argument realization; these representations emerge gradually during development.

To determine whether children have more abstract thematic mappings, many researchers have examined children's ability to generalize mapping rules to novel verbs. The results of this work have been mixed. Most novel verb production studies find that children under 3.5 years of age primarily use new verbs in ways that mimic the input, failing to produce them in other

grammatically-sanctioned constructions (see Tomasello, 2000 for a review cf. Conwell & Demuth, 2007). For example, Tomasello and Brooks (1998) exposed 2- and 2.5-year-old children to a novel verb in either a transitive or an intransitive construction while the children watched an event involving caused motion (e.g., *The puppy is meeking the ball* or *The ball is meeking*, produced while a puppy pushed a ball with his nose). Subsequently, they tried to elicit the *unmodeled* construction from the children. They found that children used the construction modeled by the adult almost 90 percent of the time despite discourse pressures to the contrary. The authors concluded that children's early sentence-level constructions are verb-specific, and that abstract verb-general constructions are constructed gradually during the preschool years.

In contrast parallel comprehension studies using the preferential looking method often find evidence for early generalization. For example, Fernandes and colleagues (2006) taught 27-to-35-month-old children novel verbs for caused motion events in the intransitive frame where the subject is the patient (e.g., "Bunny is pilking" paired with a scene in which another character pushes Bunny down to a squat). Later the children heard the same verbs in the transitive frame ("Bunny is pilking Greenbean") and correctly inferred that the subject of the utterance was now the agent of the action (Fernandes, Marcus, DiNubila & Vouloumanos, 2006). Further evidence for broad thematic generalizations comes from children's interpretation of reversible transitives. Children as young as 21 months of age systematically map the subject of a novel verb to the agent of the action (Gertner, Fisher & Eisengart, 2006).

A host of hypotheses have been put forward to reconcile the productivity present in novel verb comprehension studies with the conservatism observed in novel verb production studies. Most authors suggest that one set of findings is primary while the other largely reflects task-specific abilities or limitations. Thus, 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, Lieven, Theakston & Tomasello, 2003; Tomasello & Akhtar, 2003). In contrast, researchers favoring early abstraction have noted that the novel verb production studies are informative only if we are certain that: a) the child has assigned the verb a meaning that would allow it to participate in the relevant argument structure alternation and b) the child is sensitive to the features of the discourse that push older children to produce the unmodeled construction in the generalization phase (see e.g., Bencini & Valian, 2008; Fisher, 2002; Thothathiri & Snedeker, 2008a). Given the difficulty of learning novel verbs from the situations in which they appear (Gillette, Gleitman, Gleitman & Lederer, 1999; Maguire, Hirsh-Pasek & Golinkoff, 2006; Snedeker & Gleitman, 2004) and children's limited ability to structure discourse (Hickmann, 2000) neither assumption is trivial.

Others have questioned whether the generalizations observed in novel verb studies necessarily reflect the representations that underlie our use of known verbs (Ninio, 2005; Thothathiri & Snedeker, 2008a). When confronted with a verb that they have never heard before, children may resort to strategies that they would not ordinarily employ (e.g., translating the novel verb into a known verb that could describe the action they are seeing). Alternately, generalization in novel-verb tasks could reflect thematic mappings that are critical to acquisition, but not central to the process of production or comprehension. Such a distinction seems to underlie lexical rule analyses of argument alternations (Wasow, 1977), in which a rule is posited to explain and constrain long-term productivity, while some form of lexical storage is invoked to account for unpredictable variation across verbs. For example, one might store the structure generated by the rule for frequent verbs. It is not clear a priori whether this stored form would

preserve the abstract thematic mappings that guide the application of the rule. Considerations such as these motivate the use of paradigms that explore thematic mapping in known verbs.

Structural priming in young children

Structural priming provides a valuable tool for exploring the nature of the generalizations underlying comprehension and production. The term refers to the effects 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 one. 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. Structural priming has been demonstrated across a variety of tasks, constructions and populations (Bock & Loebell, 1990; Bock, Loebell & Morey, 1992; Branigan, Pickering & Cleland, 2000; Chang, Bock & Goldberg, 2003; Hartsuiker & Kolk, 1998; Luka & Barsalou, 2005; Pickering & Branigan, 1998; Potter & Lombardi, 1998; Scheepers, 2003, *inter alia*). These studies have had a bearing on important issues in psycholinguistics including the nature of the relationship between lexical and syntactic knowledge, the existence of deep and surface grammatical structures, and the interface between conceptual features and syntax (see Pickering & Ferreira, 2008, for a review).

The structural priming technique has several advantages for studying the ontogeny of thematic mappings. First, unlike naturalistic observation, we can experimentally control the contexts that children are placed in and manipulate the linguistic input given to them, ruling out alternate explanations for the effects. Second, we can examine how children use known verbs, avoiding the complications inherent in combining verb learning and thematic mapping in a single task. Studying known verbs also alters the nature of the inferences that we can make; as we

noted above, successful use of thematic mappings in a novel-verb generalization task does not guarantee that these mappings are used when comprehending and producing known verbs. Finally, the technique allows us to systematically vary the overlap between prime and target sentences to explore the nature of the representations involved in language use. This approach has been used extensively in structural priming studies with adults, a point to which we will return shortly.

There are six published studies to date which have explored structural priming in young children: one study from our lab that explored priming during online comprehension (Thothathiri & Snedeker, 2008a) and five studies of production priming using offline measures. We review the comprehension results first. These experiments used the dative alternation shown in 3.

3. Dative Alternation

a. Double-object dative: Pass the dog the spoon.

b. Prepositional-object dative: Pass the spoon to the dog.

Children who heard a particular form of the dative developed the expectation that a subsequent sentence would also use the same construction. Specifically, 3- and 4-year-old children heard unambiguous double-object or prepositional-object datives, like those above, and then encountered temporarily ambiguous dative utterances (*Bring the monkey the hat / Bring the money to the bear*). During the ambiguous interval, those who were primed with double-object datives were more likely to look at the potential recipient (monkey), while those who were primed with prepositional datives were more likely to look to the potential theme (money).

These findings demonstrate that children have some representation of these constructions that is spontaneously employed during language comprehension and can be extended across

verbs. However the nature of this representation is unclear. The data are consistent with three possibilities (which are not mutually exclusive).

a) The locus of priming could be a mapping between syntax and conceptual structure. For example, exposure to the double-object construction might prime a mapping between the direct object and animacy or the indirect object and inanimacy.

b) The locus of priming could be the syntactic structure itself. The prepositional-object construction might prime a syntactic structure that includes a verb-phrase attached to a prepositional phrase while the double-object construction might prime a structure that includes two noun-phrases after the verb.

c) The locus of the priming could be a mapping between syntax and semantics. The double-object construction might prime a mapping between the direct object and the recipient of a transfer event, while the prepositional object construction might prime a mapping between the direct object and the theme.

A close inspection indicates that the five production priming studies are also ambiguous with respect to the nature of the primed representations. All of these studies used the picture description paradigm, in which children either repeated a prime sentence uttered by the experimenter or simply listened to it and then described a target picture. Two related studies by Savage and colleagues explored the role of lexical overlap on priming in children from 3 to 6 using the active-passive alternation for transitive verbs (Savage, et al., 2003; Savage, Lieven, Theakston & Tomasello, 2006). They found that children in all age groups showed priming when the prime sentence used pronouns that could be repeated in the target utterance. Thus hearing or producing primes such as “*It is catching it*” or “*It got caught by it*” facilitated the subsequent production of similar active and passive sentences (e.g., *It is closing it* or *It got*

closed by it). In contrast, when non-overlapping lexical nouns were used (e.g., *The ball was caught by the net*) only the 6-year-olds showed priming. The authors concluded that while 6-year-olds have robust abstract representations, 3- and 4-year-olds rely primarily on lexically-specific representations involving pronouns and some grammatical morphemes. Notice that the children's productions in the pronoun condition provide no information about which thematic role is assigned to each syntactic position: because both the agent and the patient are described with the same pronoun (*it*), it is unclear which entity is the subject and which is the object.

The remaining production studies have all demonstrated robust structural priming in children as young as three in the absence of overlapping content words. Huttenlocher and colleagues found priming of both passive and dative constructions in 3-year-olds, 4-year-olds and 5-year olds (Huttenlocher, Vasilyeva & Shimpi, 2004; Shimpi, Gamez, Huttenlocher & Vasilyeva, 2007). In the two older groups, priming occurred regardless of whether the child produced the prime utterance, indicating that priming involves a representation that is shared by both production and comprehension. In contrast 3-year-olds were primed only when they repeated the prime sentence. A similar pattern was found in the final and most recent production study (Bencini & Valian, 2008). Young 3-year olds were given either active or passive primes and asked to describe pictures of transitive actions with inanimate agents and patients. Robust production priming was observed only in the experimental condition in which the prime sentences were repeated. Thus for the youngest children it is unclear to what extent production-specific processes were at play.

We can examine the three hypotheses described above in light of these studies. First consider the hypothesis that priming involves mappings between conceptual features and syntax. The Savage studies and the Bencini and Valian experiment controlled for conceptual mappings

by using pictures in which both the agent and patient were inanimate and belonged to similar ontological categories. In contrast, in our study and the Huttenlocher studies there was a strong confound between conceptual features and argument roles. In the case of the dative sentences, the recipients were animate, while the themes were not. In Huttenlocher and colleagues' transitive sentences, there was a more subtle conceptual confound. The ontological category of the agent and patient varied across trials but there were clear differences between the two sets: the agents were largely animates or natural forces while the patients were generally objects or places. Interestingly, the studies with the clearest controls for conceptual features (Savage, et al., 2003 and 2006; Bencini & Valian, 2008) were precisely the ones in which the priming effects were most limited (to conditions with high lexical overlap or repetition of the prime). Thus it is unclear if we can rule out a conceptual basis for *abstract* and *amodal* structural priming. In our previous comprehension study, we took an initial step toward examining the role of conceptual features in priming (Thothathiri & Snedeker, 2008a). We reasoned that if structural priming is subserved by animacy features then hearing dative constructions should alter expectations about the post-verbal argument of a transitive verb (*squeeze the bunny/bun*). We observed animacy priming from one transitive sentence to another, but found no animacy priming from datives to transitives. Thus it seems that animacy-priming in children is at least constrained by verb class.

Our second hypothesis was that priming is primarily syntactic. Perhaps the prime utterances activate a particular syntactic frame or structure leading to the expectation that the target utterance will have the same structure. This syntactic priming might then have down-stream influences on semantic processing (through the activation of verb-specific or verb-general argument roles) which ultimately result in the observed eye-movements. This proposal is difficult to distinguish from our third hypothesis that thematic mappings themselves are the locus

of priming. In the constructions that have been used to date, syntactic structure and thematic mappings are perfectly confounded. Passives and actives differ in their thematic mappings (patient → subject and agent → by-phrase vs. agent → subject and patient → object). But they also differ in their surface syntax (post-verbal PP vs. direct object NP). Similarly double-object datives and prepositional datives have different ordering of thematic roles (recipient/theme vs. theme/recipient) but also different syntactic structures (verb NP NP vs. verb NP PP). Thus to determine whether thematic role mappings are implicated in children's language use, we must systematically disentangle these factors by varying the relation between primes and targets. The research on structural priming in adults provides a model for this enterprise, so we take a brief detour now to review this literature.

Tracking down the locus of structural priming in adults

The research on production priming in adults has explored each of the above-mentioned hypotheses. While the pattern is complex, most observers agree that the findings point to priming at several different levels of representation. Several of the earliest studies suggested that priming largely depended on syntactic structure with thematic mappings playing little or no role. Two experiments were particularly influential (both appearing in Bock & Loebell, 1990). In the first experiment, the authors found that prepositional locatives (e.g., *The widow drove the Mercedes to the church*) were just as effective as prepositional datives (e.g., *The widow gave the Mercedes to the church*) in priming other prepositional datives. On their analysis the two constructions had a different set of thematic roles (theme and location in locatives; theme and beneficiary/recipient in datives) but the same syntactic structure (NP-V-NP-PP). Thus they concluded that priming appears to have a syntactic locus. But this conclusion depends on the granularity of thematic mappings. On many theories, location and recipient are subsumed under

the larger category of “goal” (e.g., Jackendoff, 1972). In fact most contemporary proposals treat both prepositional locatives and prepositional datives as examples of a single construction or event structure which is distinct from that of the double object dative (see e.g., Goldberg, 2006; Harley, 2003). If this is correct, then the above finding cannot distinguish between thematic-mappings and syntactic structure as the locus of priming.

More damning evidence against the centrality of thematic roles came from a second experiment reported in the same paper. Locative sentences (e.g., *The construction worker was digging by the bulldozer*) were no different from passive sentences (e.g., *The construction worker was hit by the bulldozer*) in priming other passive sentences despite the fact that the subject is the agent in the former and the patient in the latter. These two thematic mappings are distinct on all theories discussed earlier in the introduction. Thus this experiment suggests that there is structural priming which reflects the activation of syntactic structure independent of thematic mappings. Interpreting the null effect of thematic mappings is more risky however: no power tests were conducted and the high rate of passives in this experiment (74-80%) suggests that ceiling effects may have been an issue.

A third experiment by Bock and colleagues provided evidence for the priming of mappings between conceptual features and syntax, independent of thematic mappings (Bock, Loebell & Morey, 1992). Participants were given primes in which the animacy of the agent and the use of the passive/active construction were fully crossed (e.g. *The boat carried/was carried by five people* or *Five people carried/were carried by the boat*). Target pictures always involved an inanimate agent and an animate theme; thus producing a passive description entailed using an animate subject. The authors found independent effects of construction type and animacy: passive primes (with animate or inanimate subjects) led to more passive utterances and primes

with animate subjects (active or passive) resulted in more utterances with animate subjects. This independent effect of animacy suggests that there are direct mappings between conceptual features and syntax which bypass thematic roles and can be primed.

The first evidence for thematic role mappings as a locus of priming came more than a decade later. Chang, Bock & Goldberg (2003) noted that previous studies had either conflated thematic mappings and syntactic structure or pitted the one against the other. They suggested that the priming of thematic mappings may be too weak to overcome a syntactic mismatch or too small to detect above and beyond a syntactic effect. Accordingly, they looked for the priming of thematic mappings when syntactic structure was held constant. The critical experiment used the locative alternation (shown in 4).

4. Locative Alternation

- a. Theme-First: The maid rubbed polish onto the table.
- b. Goal-First: The maid rubbed the table with polish.

Goal-first primes resulted in more goal-first target utterances than theme-first primes. Because the two forms have the same syntactic structure, this suggested that thematic mappings could be primed. There was one important caveat however: while the two postverbal arguments did not differ in animacy (both the theme and the goal objects were inanimate), they did vary in another conceptual dimension: discreteness or individuation. Many of the goals were count nouns which denote discrete individuals (e.g., table) while many of the themes were mass nouns denoting substances (e.g., polish) or plural nouns denoting collections (e.g., pins). Plural nouns and mass nouns are similar to one another and distinct from count nouns in many respects (see Chierchia, 1998). Thus this experiment leaves open the possibility that priming involved a mapping between the conceptual features of noun phrases and syntactic functions (or alternately a

mapping between *syntactic* features of NPs, such as mass/count, and different syntactic functions).

Two other studies made a similarly suggestive case for the priming of thematic roles while leaving a conceptual door open. Hare and Goldberg (1999) and Salamoura and Williams (2007) primed dative targets with provide-with sentences (e.g., *The president rewarded the winner with the gold medal*), double-object datives or prepositional datives. Despite the difference in syntactic structure, provide-with primes had the same effect as double-object datives, presumably because both constructions place the goal before the theme. Neither of these studies, however, controlled for animacy leaving open the possibility that the locus of the effect is a mapping between the animacy features of noun phrases and syntax (as in Bock, et al., 1992).

To summarize, structural priming studies to date have provided inconclusive evidence for the activation of thematic role mappings during sentence production. Early studies (e.g., Bock & Loebell, 1990) argued against any role for the activation of such mappings. More recent studies (e.g., Chang, et al., 2003) suggest that thematic roles may play (at least) a weak role during sentence production, but some conceptual alternatives, specifically the priming of animacy and discreteness features, remain to be ruled out. In the current study, we revisited the issue by examining priming during online language comprehension in children. This will allow us to address the questions that were raised in the previous sections about the nature of structural priming in young children and the development of thematic mappings. Using the adult literature as a model, we extend the methodology used by Thothathiri & Snedeker (2008a) to disentangle the effects of conceptual mappings, syntactic structure, and thematic mappings. In Experiment I, we pitted animacy against thematic mappings and syntax to explore the hypothesis that priming is primarily driven by conceptual mappings. In Experiment II, we pitted syntactic structure

against thematic roles. Taken together, the two experiments provide convincing evidence that 4-year-old children possess abstract thematic mappings that are spontaneously invoked during online processing.

Experiment I

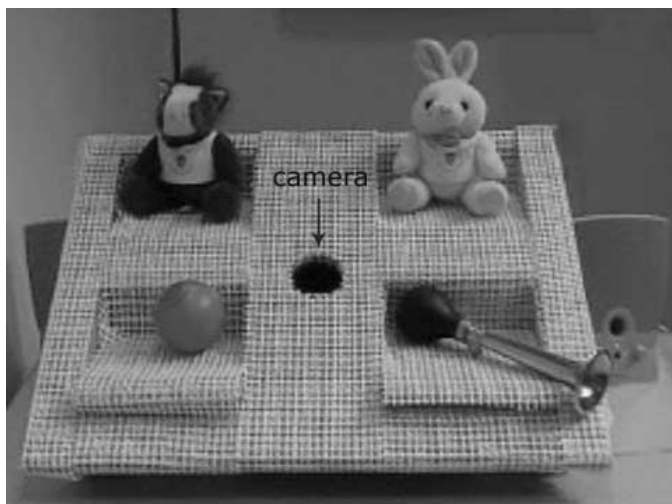
This experiment explores the possibility that structural priming in children is driven by mappings between animacy and syntax. Children are known to be sensitive to the animate-inanimate distinction from early on (Rakison & Poulin-Dubois, 2001). Animacy is strongly correlated with syntactic position which has led some theorists to suggest that selective attention to the sentential positioning of animate and inanimate nouns may precede a complete understanding of the structure of language (Slobin, 1981). In our previous experiment (Thothathiri & Snedeker, 2008a) we demonstrated priming of double-object and prepositional-object dative constructions in which animacy is robustly linked to argument structure. Both our prime and target sentence stimuli reflected this pattern: the recipients were animates and the themes were inanimate. Here, we attempted to disentangle the effect of animacy from linguistic structure by creating a third prime type in which animacy features were pitted against both the syntactic structure of the utterance and its thematic role mappings.

Participants

Sixty four young 4-year-olds (16 in each prime condition) participated (Range = 4;0 to 4;6. Mean age = 4;3. 31 male). Six other children were tested but excluded from the analyses for the following reasons: bilingual (1), provided only one usable trial (2), receptive language delay (1), and distracted during the stories (2).

Procedure

Participants were seated in front of an inclined podium with four quadrants (Figure 1). A camera at the center of the podium recorded their eye movements in response to utterances that were played from speakers. Each videotape was coded later to determine the relation between the eye-movements and the utterances. This method yields results that are comparable to those obtained from head-mounted eye-trackers (Snedeker & Trueswell, 2004).



Story: The children were angry. They ran home, and the old woman knew they were upset. **To calm them down, she showed a toy to the girl. Then she read a story to the boy.**

Instruction: **Now you can send the horse the ball / send the horn to the bunny.**

Figure 1. Experimental setup. On critical trials, the last two sentences of the story were *primes*; the subsequent instruction was the *target*. Prime and target sentences are shown in bold.

Children were told that they were going to listen to the voices of two friends (Bob and Susan) from the computer. Bob would tell them a story; Susan would tell them how to play with the toys. The primes appeared in Bob's story, while the targets appeared in Susan's instructions. This design ruled out the possibility that any priming effects we find are due to expectations about particular speakers or strategic effects related to the act-out task alone. On each trial, the experimenter brought out four toys (2 animals and 2 objects). She placed the toys on the shelves while labeling them. Then she played an audio file consisting of Bob's story followed by Susan's instruction. Children were told to listen to the entire instruction before acting it out.

Stimuli

Each session consisted of 12 trials (7 filler and 5 critical trials). Each filler trial contained two transitive instructions, one with an animate direct object (e.g., *Poke the bear*) and another with an inanimate direct object (e.g., *Hide the shirt*) (See Appendix for a complete list). Filler trials were interspersed with the critical trials merely to mask the purpose of the experiment. Critical trials contained dative instructions. On these trials, the last two sentences in the story served as primes while the instruction that followed the story was the target utterance. The prime sentences were one of four types (1-4).

1. Intransitive: *The children slept really well.*
2. Double-object (DO) dative: *She read the girl a story.*
3. Prepositional-object (PO) dative: *She read a story to the girl.*
4. Animacy-reversed PO: *She carried the girl to the bed.*

The target instructions were always temporarily ambiguous DO or PO datives (e.g., *Send the horse the ball* or *Send the horn to the bunny*). See Appendix for a list of all the primes and instructions. Children were randomly assigned to one of the eight possible conditions (4 prime types x 2 target types). Primes and targets always used different verbs.

On critical trials, there were two toys in front of the child that had the same phonological onset (e.g., horse and horn; see Figure 1). The corresponding target instruction was either a DO (e.g., *send the horse the ball*) or a PO (e.g., *send the horn to the bunny*) dative. Thus the beginning of the first postverbal noun (*hor...*) was compatible with both an animate recipient (horse) and an inanimate theme (horn). We calculated the total proportion of time that children were looking at the two items (hereafter referred to as the animal and the object) as a proportion

of all their looks to the visual scene. The temporal interval for analysis was independently determined from children's latencies during the filler trials (see below).

The intransitive primes were intended to serve as a baseline. They contain no postverbal arguments and are therefore not expected to influence children's looks to the animal or the object during the postverbal portion of the target instruction. In contrast, on the basis of our previous results, we expected DO and PO primes to influence children's looks in different ways. Specifically, PO primes should lead to a greater preference for the inanimate theme immediately after the verb compared to the DO primes. The fourth prime type (animacy-reversed PO) was included to test whether priming, if present, was entirely due to mappings between animacy features and syntax. These primes contain an animate noun right after the verb, just like DO datives but unlike PO datives. However their syntactic structure and the ordering of thematic roles are similar to PO but not DO datives. Thus they can help disambiguate between the priming of animacy and the priming of either syntactic structures or thematic mappings.

Temporal Interval for Analysis

When can we expect to see eye movements in the children in response to critical portions of a sentence? Estimates of saccade latencies for different ages and different tasks are not known. In picking a temporal interval, we wanted to minimize Type 2 errors that might result from selecting a pre-determined arbitrary window (e.g., starting from 200 ms after critical word onset as is often done in adult studies). At the same time, we wanted to also minimize the likelihood of Type 1 errors that might result from analyzing multiple successive intervals or hand-picking an interval based on visual inspection of the data. One unbiased way to determine the temporal window is to use eye movement latencies from the population of interest using no-interest, unanalyzed trials. For each of the two experiments reported in this paper, we picked 7 filler trials

for 7 different subjects chosen at random for a total of 14 filler trials. Half of these trials had an animate direct object (*Kiss the dog*). The other half had an inanimate direct object (*Hold the box up over your head*). In half of the trials (*Hold the box...*), the direct object was not the final word in the sentence. We measured children's latency to look at the entity mentioned from the onset of the noun. We used the mean \pm 1 SD calculated from these 14 filler trials to analyze our critical trials (Mean=567 ms, SD=233 ms). Thus the interval was 333-800 ms from noun onset.

Coding

Eye movements were coded as being to the center, away from the display, 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. For 10% of the trials, eye movements were coded by a second coder. Intercoder reliability was 79% (Cohen's Kappa =0.74).

In our previous study we found that 4-year-olds had a preference for looking at the animal irrespective of the experimental condition and that looking time to the *dispreferred* item, i.e., the object, was the measure most sensitive to priming (Thothathiri & Snedeker, 2008a). We found a similar preference for looking at the animal in the current experiment (difference between looking time to animal minus object > 0 ; $t(63)=4.048$; $p<.001$). Thus, in accordance with the previous study, we report looking time to the object as our dependent measure.¹

¹ We also analyzed looking time to the preferred item (i.e., the animal). In Experiment I, there was an overall effect of prime [$F(3, 56) = 3.880$; $p<.02$] with looking time to the animal being highest in DO prime condition and lowest in the PO and animacy-reversed conditions, with baseline in-between (as expected). However, none of the individual contrasts compared to the baseline were significant. In Experiment II, looking time to the animal was higher in the

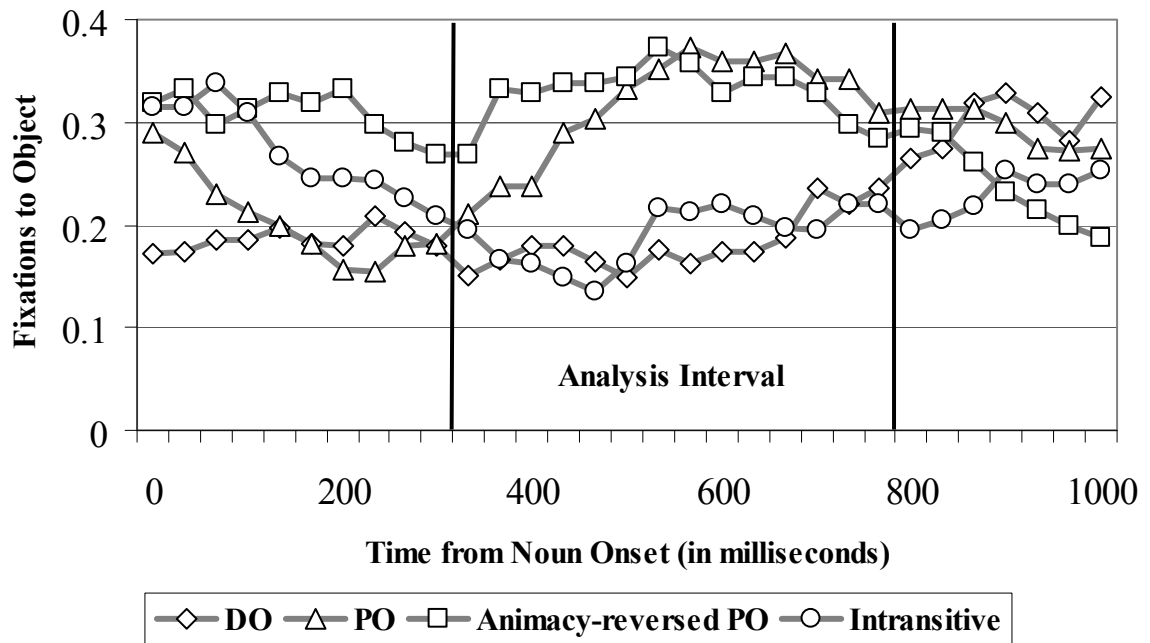


Figure 2. Experiment I: Proportion of fixations to the object in 4 prime conditions.

goal-first than in the theme-first priming condition (as expected), but this effect was not significant [$F(1, 28) = 0.537; p > .4$].

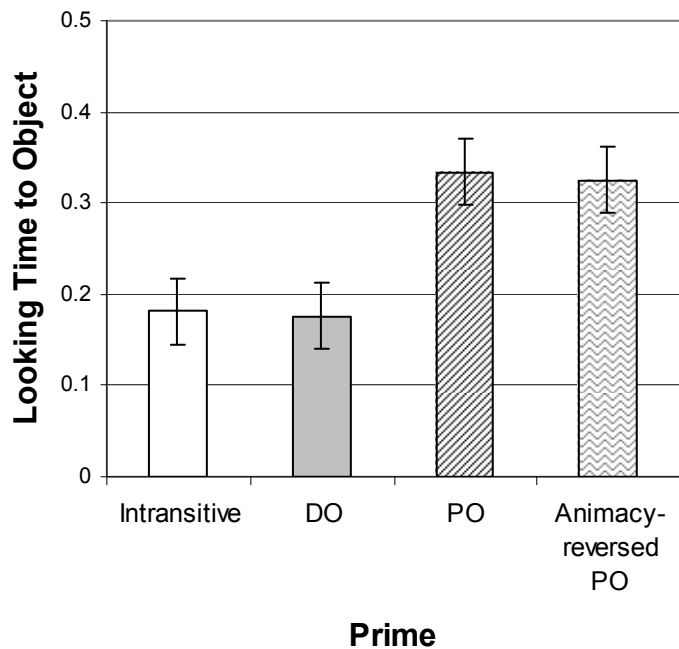


Figure 3. Experiment I: Mean looking time to the object in the analysis interval

Results and Discussion

Children performed the correct action on 96% of the trials showing that they could interpret the dative sentences correctly. Figure 2 shows their eye movements to the object in each of the prime conditions. Qualitatively, fixations to the object in the PO and animacy-reversed PO conditions look higher than those in the DO and intransitive conditions. This was confirmed by the statistical analysis. We computed the average looking time to the object for each participant during the analysis interval. We excluded those trials where participants were looking away from the four items for more than two-thirds of the interval. This eliminated 8% of the trials. A 4x2 ANOVA² (Prime Type x Target Type) of mean looking times revealed a significant effect of

² We report participant analyses only. Our experiments were necessarily short due to the age of our participants. Each experiment contained only 5 critical items.

target [$F(1, 56) = 9.124, p < .01$]. Looking time to the object was higher in the PO target condition ($M=0.309$) than in the DO target condition ($M=0.199$; $S.E.=.026$) suggesting that children were able to disambiguate the noun at some point during the analysis interval.³

Critically however, there was a significant effect of prime [$F(3,56) = 5.770, p < .01$] and no interaction between prime and target [$F < 1, p > 0.8$]. Planned comparisons revealed the following pattern (Figure 3): the DO condition ($M=0.176$) did not differ significantly from the baseline intransitive condition ($M=0.181$; $S.E.=0.036$; $p > .9$) but looking time to the object was higher than the baseline intransitive in both the PO condition ($M=0.334$; $p < .01$) and the animacy-reversed PO condition ($M=0.325$; $p < .01$).

The absence of any difference between the DO and intransitive conditions is open to two interpretations. First, it is consistent with the possibility that children lack a primeable representation of the double-object construction. Perhaps children have an overarching preference for the prepositional dative - and therefore for looking at the object - that our DO-priming manipulation could only partially overcome. An alternate possibility is that the null effect is due to a limitation of our method. Looking time to the object was low in both of these conditions suggesting that our ability to distinguish them may be limited by floor effects. Importantly, neither possibility muddles the interpretation of our primary finding, which is that animacy-reversed and typical PO primes influenced children's eye movements in the same direction.

³ In a gating task given to two adults, the nouns were disambiguated an average of 400 ms after onset (Thothathiri & Snedeker, 2008b). Thus our analysis interval here (333 to 800 ms) likely included eye-movements in response to disambiguating phonological information.

The results for the animacy-reversed primes indicate that animacy-to-syntax mappings are not the primary locus of structural priming in this paradigm. The effects of these primes and the PO primes were indistinguishable, even though they had precisely the opposite animacy-to-syntax mappings. The animacy-reversed primes had animate direct objects (like the DO primes), but they led our participants to expect inanimate direct objects for dative verbs just as the PO primes did. Both of our other hypotheses are consistent with these effects. Either the syntactic structure (Verb NP PP) or the thematic mapping (e.g., direct object → theme, prepositional phrase → goal/recipient) that is common to both PO sentence types could have been primed. The priming of either type of representation would lead to the expectation that the direct object would be inanimate, resulting in the observed pattern of eye-movements. We attempted to disambiguate between the two possibilities in Experiment II.

Experiment II

In Experiment II, we asked whether the representations that underlie the structural priming of datives in 4-year-olds are purely syntactic, or involve thematic role mappings.

Participants

Thirty-two young 4-year-olds (16 in each prime condition) participated (Range = 3;11 to 4;5. Mean age = 4;2. 18 male). Three other children were tested but excluded from the analyses because they looked away from the podium or failed to make eye movements during the instructions on a majority of the trials.

Stimuli

We used the same design as in Experiment I except that prime sentences were now one of two locative structures:

1. Goal-first locative: *They loaded the truck with the hay.*
2. Theme-first locative: *They loaded the hay on the truck.*

The target sentences were the same DO and PO datives used in Experiment I. See Appendix for a list of the experimental stimuli. Children were assigned randomly to one of the four possible conditions (2 prime types x 2 target types).

The two prime sentence types have the same syntactic structure (Verb Noun-Phrase Prepositional-Phrase) but they differ in whether the theme or the goal of the transfer is positioned immediately after the verb. If the priming observed in Experiment I is due solely to children's representations of syntactic structure, we would expect no difference between these two prime conditions. Alternately, if priming is targeting children's representations of thematic mappings, we would expect the two prime conditions to be different, with theme-first locatives increasing looks to the object compared to goal-first locatives.

Coding

Eye movements were coded using the same procedure as in Experiment I. For 10% of the trials, eye movements were coded by a second coder. Intercoder reliability was 87% (Cohen's Kappa =0.84).

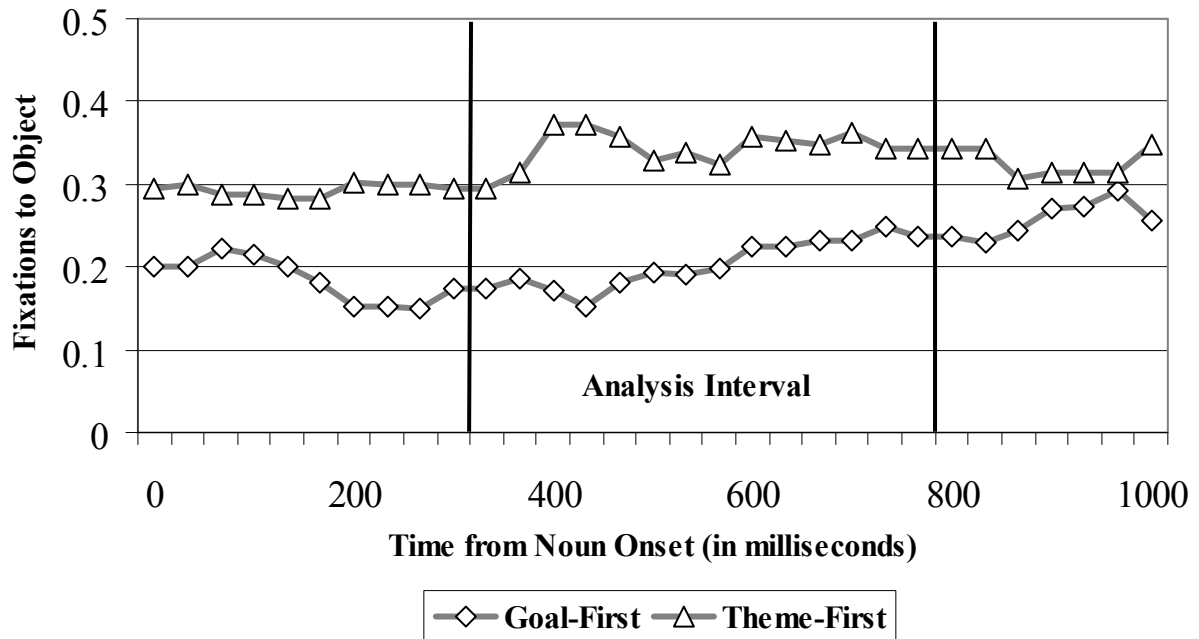


Figure 4. Experiment II: Proportion of fixations to the object in 2 prime conditions.

Results and Discussion

Children performed the correct action on 96% of the trials.⁴ Figure 4 shows their eye movements to the object in the two prime conditions. As in Experiment I, we calculated average looking time for each subject during the analysis interval. Fifteen percent of the trials were excluded because children were looking away from the four items for more than two-thirds of the interval. A 2x2 ANOVA (Prime Type x Target Type) of mean looking times revealed a significant effect of

⁴ Due to experimenter error, action information was not available for two of the children. This percentage was calculated from the remaining 30 participants.

prime only [$F(1, 28) = 6.079$; $p < .03$].⁵ Looking time to the object was significantly higher in the theme-first condition ($M = 0.371$) than in the goal-first condition ($M = 0.219$; $S.E. = .044$). The two types of prime sentences had the same syntactic structure but led to different patterns of eye movements, suggesting that the locus of priming was not *purely* syntactic.

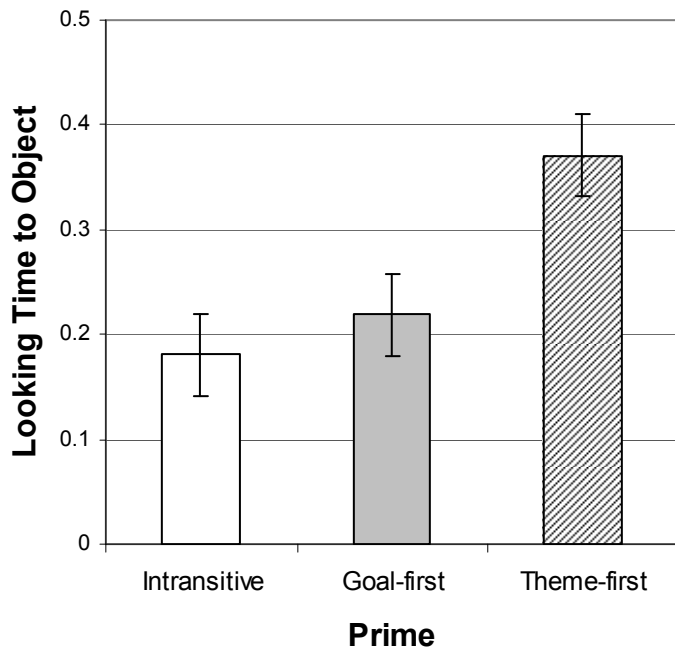


Figure 5. Experiment II: Mean looking time to the object in the analysis interval (intransitive condition reproduced from Experiment I)

In fact, our results show no detectable effect of priming syntactic structures. We compared looking time to the object for the two locative constructions to the intransitive

⁵ A visual inspection of Figure 4 suggests that the priming effect may have preceded the analysis interval. We analyzed looking time to the object in a prior interval (0 to 300 ms). The means in the two conditions were numerically different (goal-first: 0.189, theme-first: 0.320) but this difference was barely marginal [$F(1,28)=2.908$; $p=.1$].

condition tested earlier (in Expt. I).⁶ Both locatives have a prepositional syntactic structure. If these sentences led to priming of the prepositional dative, we might expect greater looking to the object for either of these primes compared to the baseline intransitive. This is not the pattern that we found. A one-way ANOVA of the three prime conditions showed an overall effect of prime [$F(2, 45)=6.518; p<.01$]. Theme-first locatives led to significantly greater looks to the object compared to intransitives ($p<.01$) but the contrast between goal-first locatives and intransitives was not significant ($p>.5$) (Figure 5).

This looking time pattern suggests that priming in our experiments was primarily thematic. Dative themes are typically inanimate while dative goals (recipients) are not. Compared to intransitive primes, theme-first datives (Expt. I) and theme-first locatives (Expt. II) led to increased looking to a likely inanimate theme. Goal-first datives and goal-first locatives did not.

Temporal Dynamics of Children's Eye Movements

At what point in the sentence does priming begin to influence children's eye movements? Adults have been shown to anticipate properties of a verb's arguments soon after hearing the verb and prior to hearing the arguments themselves (e.g., Altmann & Kamide, 1999). In a previous priming study (Thothathiri & Snedeker, 2008a) we found weak evidence for anticipatory movements in 4-year-old but not 3-year-old children. For the two experiments

⁶ This comparison is justified because we employed a between-subjects design that used the same visual stimuli, target sentences and coding/analysis procedures. The two experiments tested children from the same population (4-year-old children from around Cambridge, MA) and employed the same coders. Under these circumstances, the assignment of an experimental condition to a particular experiment is arbitrary.

reported here, we evaluated eye movements to the object in the 0-300 ms interval, which came prior to the main interval of analysis. Mean looking time to the object in the three theme-first prime conditions was as follows: PO (0.221), animacy-reversed PO (0.355) and theme-first locative (0.32). As in the main analysis, we compared looking time in these conditions to the baseline intransitive condition (0.292). None of these contrasts were significant (PO $p > .2$, animacy-reversed PO $p > .3$, theme-first locative $p > .7$). Thus, there was no suggestion that theme-first prime conditions increased looks to a probable theme prior to our main post-noun-onset interval of analysis.

General Discussion

In this paper we explored three hypotheses about the locus of structural priming during children's language comprehension. In Experiment 1 we demonstrated that structural priming could not be reduced to mappings between syntax and animacy. In fact, reversing these mappings appeared to have no effect whatsoever. In Experiment 2, we pitted syntactic structure against the ordering of thematic roles. We found evidence for robust priming of thematic mappings but no evidence for the priming of syntactic structure. These results are relevant to three different literatures: 1) research on children's acquisition of thematic mappings; 2) studies on the role of thematic mappings in structural priming; and 3) theoretical work on the nature of argument realization.

The acquisition of thematic mappings

The current study provides some insight into children's knowledge and use of abstract mappings between thematic roles and syntactic structure. As noted in the introduction, there has been an active debate on the nature of children's grammatical representations in language

acquisition and the pathway by which these representations are acquired. Much of this discussion has centered on the acquisition of thematic mapping rules (or sentence-level constructions). Our results show that children as young as four years of age have abstract thematic mappings that allow them to generalize across events as different as giving, reading, loading and carrying. Their representations capture the commonalities between the participants in these events and they expect the noun phrases that refer to these participants to appear in similar syntactic positions. Thus our results are consistent with previous studies that show that young children are able to correctly map thematic roles to the appropriate syntactic positions in novel transitive and intransitive sentences (Fernandes, et al., 2006; Gertner, et al., 2006).

Critically, we find that children rapidly and spontaneously employ these thematic mappings to understand sentences as they unfold. Nothing in our task requires (or rewards) this behavior. The sentences use known verbs — if children habitually use lexically-specific mappings these would be sufficient for understanding the instructions and performing the task. The target utterances are rapidly disambiguated (400ms) and because we fully crossed prime and target type, the primes do not predict how the targets will be resolved. The use of abstract thematic mappings under these conditions suggests that these representations subserves preschoolers' everyday language comprehension.

Whether younger children use abstract thematic mappings during comprehension remains to be determined and is crucial to resolving the question of where these abstractions come from. In our prior work we found structural priming of datives in young three-year-olds and we are currently pursuing parallel work with two-year-olds. But we would hate to see the question of *when* priming appears supplant the question of *what* is actually primed. The present study with 4-

year-olds represents a first step towards understanding the nature and scope of children's grammatical representations.

Thematic mappings as a locus of structural priming

Bock and Loebell's (1990) paper has had a strong influence on how psycholinguists think about structural priming. The presence of robust priming in the absence of thematic overlap — and the lack of any detectable effects of thematic mappings — have led many to view structural priming as a phenomenon based primarily on the surface structure of the utterance. As we noted, three studies of production priming in adults suggest that thematic mappings can be primed (Chang, et al., 2003; Hare & Goldberg, 1999; Salamoura & Williams, 2007). However in all three cases, systematic conceptual differences between the nouns that occupied the different thematic roles could have potentially served as a basis of mapping between conceptual features and syntax.

The present studies eliminate two important conceptual correlates of thematic roles, namely animacy and discreteness. We discuss the issue of animacy first. In Experiment I, animacy priming was pitted against the priming of syntactic or thematic structure. Animacy-reversed PO primes led to similar effects as PO datives with which they shared linguistic structure and different effects from DO datives with which they shared the animacy of the first postverbal argument. In Experiment II, all of the postverbal arguments in the primes were inanimate. Nevertheless the two prime conditions (goal-first and theme-first) had distinct effects. This is not to say that animacy is irrelevant; previous research clearly indicates that it can play a role under some circumstances (Bock, et al., 1992; Hartsuiker & Kolk, 1998). But these experiments do suggest that animacy priming is insufficient to explain the structural priming seen here.

Animacy is not the only conceptual feature that could potentially underlie structural priming. For example, in our discussion of the study by Chang and colleagues (2003) we noted that discreteness might play a role in locative-to-locative priming. The themes and goals in locative structures typically differ in their discreteness; the themes (e.g., hay) are less discrete or indivisible than the goals (e.g., truck) creating a confound between thematic role mappings and mappings of the conceptual features of the nouns. In Experiment 2 we were able to avoid this conceptual confound by measuring priming from locative sentences like “*They loaded the hay on the truck*” to dative sentences like “*Bring the couch to the tiger*”. Both the theme and the goal in our dative sentences were singular count nouns for discrete entities. Thus any priming of discreteness to syntactic position would not transfer to these utterances. Of course, we do not claim to have neutralized all possible conceptual differences between the themes and goals. In fact, some conceptual differences are inevitable: themes like “hay” and “couch” are likely to be more moveable than goals like “truck” or “tiger”. Properties like these are often argued to be entailments of thematic roles rather than properties of the entities that fill those roles (consider e.g., *Bring the mountain to Mohammed*. Dowty, 1991; Levin & Rappaport-Hovav, 2005). Thus it remains to be seen whether a conceptual theory that appeals to these properties is substantively different from the thematic mapping hypothesis.

In sum, our results corroborate previous studies that found priming of thematic mappings, while extending these findings to a new population and task and ruling out some conceptual factors that were previously not controlled (Chang, et al., 2003; Hare & Goldberg, 1999; Salamoura & Williams, 2007). One feature of our results is particularly interesting: we find an effect of priming thematic mappings even when syntactic and thematic structures are opposed to one another (see Experiment II Discussion). In many respects our design parallels that of the

Bock and Loebell's passives experiment. We present primes with a single syntactic structure but two different thematic structures and then examine whether the thematic difference affects the processing of target utterances. These are precisely the circumstances under which Chang and colleagues (2003) suggest that thematic priming will not be detected.

There are numerous differences between our study and the prior production experiments which might explain this discrepancy. First, we used dative constructions while the two production studies that are most often cited in this context used the active/passive transitive construction (Bock & Loebell, 1990; Bock, et al., 1992).⁷ While it is unclear what effect this might have, the two alternations differ on many dimensions. The by-phrase in the passive is absent more often than not and appears to be an adjunct. In contrast the prepositional phrase in the PO dative is typically mandatory and is analyzed as an argument of the verb. In addition, while theories vary widely, there is little overlap in the mechanisms that are invoked to account for the passive and the dative alternation. Passivization is more often analyzed with rule-like mechanisms at the syntactic level while the dative alternation is more likely to receive a semantic or lexical analysis (see Levin & Rappaport-Hovav, 2005). In fact, passivization can apply to both forms of the dative suggesting that it may occur at a different level of representation (*The paper was given to John by the courier / John was given the paper by the courier*). Thus we might expect semantic factors to play a greater role in the priming of datives, and syntactic factors to play a greater role in the priming of passives.

⁷ Experiment 1 in Bock and Loebell (1990) employed the dative construction. However, as we noted above, it is not clear that this study effectively disentangled syntax and thematic structure. On most contemporary theories their critical prime (the prepositional locative) has both the same syntactic structure and the same thematic mappings as the prepositional dative.

Second, participants in the current study were four-year-old children while those in the earlier experiments were adults. It is certainly possible that young children are more sensitive to the priming of thematic mappings and less sensitive to the priming of syntactic structure compared to adults but we know of no direct evidence that bears on this question. There is an old and extensive literature on children's sentence comprehension which suggests that they rely more on conceptual features and less on syntax than adults (see e.g., Stohner & Nelson, 1974; Chapman & Kohn, 1978; Corrigan, 1988). For example, while preschoolers are clearly sensitive to word order (Bever, 1970; Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987), they are more likely than adults to misinterpret transitives with inanimate subjects (e.g., *The flowers watered the girl*). Note however that this line of research compares mappings from conceptual features to thematic roles with mappings from syntax to thematic roles. Such studies cannot address the relative strength of syntactic representations and thematic mappings.

Third, we manipulated the prime type between subjects while previous studies used a within-subjects design. Within-subject designs are typically preferred in the adult sentence processing literature because they minimize the possibility that participants develop strategies over the course of the experiment. Two features of our study make it unlikely that our priming effects were strategic. First, the primes and targets appeared in the context of different tasks (stories versus instructions). Second, our participants were preschoolers, an age group notoriously poor at devising, selecting and employing new strategies (see Flavell, Miller & Miller, 2002 for a review). However, it is possible that our between-subjects manipulation allowed the priming effect to accumulate over time increasing our chances of detecting it. This would be consistent with extant data and implicit learning accounts of structural priming (Bock & Griffin, 2000; Chang, Dell & Bock, 2006). To test this possibility, we compared priming during the first two

trials to that during the last two trials of Experiment II. A 2x2 ANOVA (Prime x Trial Position) revealed a marginal effect of prime [$F(1, 30)=3.094$; $p=.089$] but no effect of trial position and no interaction [$F's < 1$; $p's > .5$]. Thus our between-subjects manipulation is unlikely to be the main reason for the difference from previous studies.

Fourth, we studied comprehension instead of production. There is a current debate in the field about whether comprehension-priming is more lexically sensitive than production-priming (Arai, Van Gompel & Scheepers, 2007; Thothathiri & Snedeker, 2008b) but we know of no evidence that suggests that it may be more thematically sensitive. However, it is worth noting that production and comprehension vary in ways that are clearly relevant to this question. During production the representation of an event structure logically precedes its syntactic encoding. In contrast during comprehension the understanding of event structure follows syntactic decoding. Thus, if more recent representations have a more robust influence on subsequent processing, we might expect thematic priming to be greater in comprehension than production. In fact, the specific comprehension task that we used may have heightened the salience of thematic relations. Because participants had to carry out the action by manipulating the objects, it is possible that they were more sensitive to the roles that those objects played in the event. It is worth noting however that priming in our study is unlikely to be solely due to action-planning. Unlike target sentences, prime sentences were not enacted. Nevertheless, it remains to be seen whether eye-tracking paradigms that do not use an act-out task can detect similar priming (Arai, et al., 2007; cf. Thothathiri & Snedeker, 2008b).

Thematic priming and theories of argument realization

The study of thematic priming has the potential to inform theories of argument realization. Given a robust paradigm for eliciting thematic role priming, the pattern of transfer from one

construction to another might allow us to draw inferences about the relations between those constructions and the nature of the roles themselves. Clearly we are quite a distance from this ideal. Nevertheless it may be useful to explore how the priming observed in these studies can be explained under different theories of argument realization.

Argument structure alternations — like the datives and locatives — present a challenge for theories of argument realization. If syntactic expression of arguments depends solely on the set of thematic roles in the semantic structure, then it is surprising that two very similar propositions can be expressed using different surface syntactic forms. There are three ways for a theory of argument realization to account for this variation. First, the variation can be built into the interface between semantics and syntax by proposing two distinct mapping rules, one for each construction. On this account the natural locus of thematic priming is the rules themselves. In a construction grammar framework the alternating forms represent different constructions, each consisting of an associated syntactic and semantic structure (Goldberg, 2006). In this case the construction itself could be the unit of priming.

Second, argument structure alternations could reflect subtle differences in the semantic structure of the two forms. For example, Harley (2003) argues that double-object datives and prepositional datives have the event structures given in 5a and 5b respectively. On such a theory event structure itself is a potential locus for priming.

5a. Double-object dative: X CAUSE Z TO HAVE Y

5b. Prepositional dative: X CAUSE Y TO BE AT Z

A third alternative is that the alternations reflect syntactic movement operations rather than differences in the base-generated structure. For example, Baker (1988, 1997) argues for a one-to-one mapping between thematic roles and the underlying syntactic structure of an utterance. He

suggests that the prepositional dative is the base form with the double object dative arising via movement and incorporation. On this theory the natural locus for priming in the dative construction is either the surface structure itself or the transformation involved in creating the double-object structure.

All of these theories may be adequate for explaining dative-to-dative or locative-to-locative priming. Given the need to acknowledge the existence of both forms, all theories of argument realization must posit some level of analysis at which they are distinct. The pattern of priming across constructions provides a more interesting challenge, particularly because most theorists provide quite different analyses for the locative and dative alternations. For example, Baker treats the dative alternation as a case of syntactic movement (see above) but argues that the two forms of the locative have different event structures (1997).

Our findings suggest that prepositional datives, animacy reversed prepositionals and theme-first locatives form an equivalence class. All three prime types are reliably different than the intransitive baseline and all three are equally good at biasing children to interpret the direct object of a dative verb as a potential theme. Interestingly, these three utterances would all receive the same analysis under most contemporary theories of argument realization. For example, for Goldberg (2006) they are instances of the caused motion construction; for Harley (2003) they have event structure in 3b; and for Baker (1997) they would all have the same deep and surface syntax. At first glance, the double-object dative and the goal-first locative have a parallel similarity: in both constructions the theme appears in the second postverbal position and the direct object position is filled with a noun phrase bearing another role. However, no theory that we know of treats the two constructions as equivalent. For example, Baker (1997) analyzes the first argument in what we have called the goal-first locative as a *theme* (by which he means

the entity impacted by the action) but analyzes the first argument of the double-object dative as a displaced recipient or goal. Similarly, Goldberg (1995) attributes these utterances to two unrelated constructions. It is important to note that our data are equivocal about whether these two utterance types form an equivalence class. While double-object datives and goal-first locatives appear to have the same effect on the interpretation of temporarily ambiguous datives, this effect is no different from our baseline intransitive condition. As we noted earlier the absence of a difference between the baseline and double-object dative conditions could indicate that children fail to robustly represent this dative construction or it could be attributable to floor effects in our looking time measures. To understand the relation between the double-object dative and the goal-first locative, we will need to resolve this issue. Nevertheless our present data demonstrate that young children have a robust representation of at least one set of thematic mapping principles (those involved in the caused motion construction) that are consistent with current theories of argument realization.

Final Words

The two experiments reported here provide evidence for the priming of thematic role mappings in four-year-olds. These data speak to the nature of the representations that subserve everyday language comprehension at a critical stage in development. But they also suggest a host of questions that could be asked about these mappings in mature comprehenders. Although the full set of conditions under which abstract comprehension priming occurs remain unclear, the potential of this phenomenon for understanding the syntax-semantics interface suggests that it be worthwhile to pursue the question further.

Acknowledgments

This work was supported by National Science Foundation Grant BCS-0623845 to J.S. We thank Alison Young, Aditi Balakrishna, Katharine Needham, Noemi Hahn and Amanda Worek for help in collecting and coding the data and Cynthia Fisher for thoughts and conversations that led to this work.

Appendix

Experiments I & II: List of filler trial instructions

1. Now you can tickle the zebra. Next swing the sock.
2. Now you can open the book. Next squeeze the elephant.
3. Now you can poke the bear. Next hide the shirt.
4. Now you can hold the box up over your head. Next shake the frog up and down.
5. Now you can smell the crayon. Next bounce the donkey up and down.
6. Now you can kiss the dog. Next rub the shell.
7. Now you can pick up the pen. Next scratch the tiger.

Experiments I & II: List of critical trial instructions (matched in order to the primes below)

1. DO: Now you can bring the cow the spoon;
PO: Now you can bring the couch to the tiger.
2. DO: Now you can pass the monkey the hat;
PO: Now you can pass the money to the bear.
3. DO: Now you can send the horse the bottle;
PO: Now you can send the horn to the frog.

4. DO: Now you can toss the pig the fork;

PO: Now you can toss the pillow to the dog.

5. DO: Now you can hand the lion the stick;

PO: Now you can hand the light to the bunny.

Experiment I: List of critical trial primes

<i>Trial #</i>	<i>Prime Sentences By Type</i>
1	<p>Intransitive: The children slept really well. They woke up bright and early the next morning.</p> <p>DO: First she read the girl a story. Then she taught the boy a song.</p> <p>PO: First she read a story to the girl. Then she taught a song to the boy.</p> <p>Animacy-reversed PO: So she playfully dragged the boy to the bedroom. Then she carried the girl to the bed.</p>
2	<p>Intransitive: She winked. The boy smiled.</p> <p>DO: So the boy sang the woman a song. Then the woman fed the children the sandwiches.</p> <p>PO: So the boy sang a song to the woman. Then the woman fed the sandwiches to the children.</p> <p>Animacy-reversed PO: First, the boy pushed the girl to the top. Then, the girl slid the boy to the bottom.</p>
3	<p>Intransitive: That night, the boy did not sleep well at all. He woke up many times.</p> <p>DO: To calm them down, she showed the girl a toy. Then she read the</p>

	<p>boy a story.</p> <p>PO: To calm them down, she showed a toy to the girl. Then she read a story to the boy.</p> <p>Animacy-reversed PO: So she drove the children to the store. Then she carried the girl to the store window.</p>
4	<p>Intransitive: The boy smiled. The girl laughed loudly.</p> <p>DO: So she fed the girl a cookie. Then she sang the boy a lullaby.</p> <p>PO: So she fed a cookie to the girl. Then she sang a lullaby to the boy.</p> <p>Animacy-reversed PO: So she dragged the children to the slide. Then she slid the boy to the bottom.</p>
5	<p>Intransitive: The old woman winked. The children laughed heartily.</p> <p>DO: He went up and showed the girl the string. Then the woman taught the children a knot.</p> <p>PO: He went up and showed the string to the girl. Then the woman taught a knot to the children.</p> <p>Animacy-reversed PO: So she drove the children to the mall. Then she pushed the children to the store.</p>

Experiment II: List of critical trial primes

<i>Trial #</i>	<i>Prime Sentences By Type</i>
1	<p>Goal-First: First they loaded the truck with the hay. Then they splashed the barn floor with water.</p> <p>Theme-First: First they loaded the hay on the truck. Then they</p>

	splashed water on the barn floor.
2	Goal-First: The children packed a basket with the sandwiches. After they finished eating, they rubbed the picnic table with some polish. Theme-First: The children packed the sandwiches in a basket. After they finished eating, they rubbed some polish on the picnic table.
3	Goal-First: First they loaded a cart with some dirt. Then they sprayed the flowers with water. Theme-First: First they loaded some dirt into a cart. Then they sprayed water on the flowers.
4	Goal-First: So she splashed the children's heads with warm water. Then she rubbed their hair with some shampoo. Theme-First: So she splashed warm water on the children's heads. Then she rubbed some shampoo on their hair.
5	Goal-First: So they packed a crate with the paint boxes. When they got to the barn, they sprayed the wall with the paint. Theme-First: So they packed the paint boxes into a crate. When they got to the barn, they sprayed the paint on the wall.

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