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ScienceDirect

Journal of Memory and Language 59 (2008) 97–113

Journal of Memory and Language

www.elsevier.com/locate/jml

Abstract sentence representations in 3-year-olds: Evidence from language production and comprehension

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Received 29 September 2006; revision received 3 December 2007

Abstract

We use syntactic priming to test the abstractness of the sentence representations of young 3-year-olds (35–42 months). In describing pictures with inanimate participants, 18 children primed with passives produced more passives (11 with a strict scoring scheme, 16 with lax scoring) than did 18 children primed with actives (2 on either scheme) or 12 children who received no priming (0). Priming was comparable to that reported for older children and adults. Comprehension of reversible passives with animate participants before and after priming was above chance but did not improve as a result of priming. Young 3-year-olds represent sentences abstractly, have syntactic representations for noun, verb, "surface subject", and "surface object", have semantic representations for "agent" and "patient", and flexibly map the relation between syntax and semantics. Taken together with research on syntactic categories in 2-year-olds, our results provide empirical support for continuity in language acquisition.

Keywords: Language acquisition; Syntactic priming; Syntax; Semantics; Sentence production; Sentence comprehension; Passives

How abstract are children's early syntactic representations? According to the position we call Lexical Specificity, children's early sentence representations are concrete and organized around specific lexical items (Childers & Tomasello, 2001; Lieven, Pine, & Baldwin, 1997; Olguin & Tomasello, 1993; Tomasello, 1992, 2000a, 2000b). According to Early Abstraction (Gertner, Fisher, & Eisengart, 2006), in contrast, children's early word- and sentence-level representations are abstract from the beginning of combinatorial language. Since Early Abstraction suggests faster and more abstract learning (Casenhiser & Goldberg, 2005; Gertner et al., 2006; Marcus, Vijayan, Bandi Rao, & Vishton, 1999; Valian & Casey, 2003) than Lexical Specificity posits, much hangs on children's early sentence representations.

To examine the abstractness of children's early representations, we test "young" 3-year-olds (children between the ages of 35 and 42 months) for their production of passives via syntactic priming and for their comprehension of fully reversible passives. This is the first study simultaneously to use production and comprehension data.

The debate over abstraction in child language comes in two parts: (1) whether the child represents syntactic categories such as verb, noun, adjective, and determiner and (2) whether the child represents abstract sentence patterns and the systematic links between syntactic positions and meaning. We focus on the second achievement, the sentence-level representations that, in the passive, connect semantic notions like "agent" to the

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0749-596X/$ - see front matter
doi:10.1016/j.jml.2007.12.007

by phrase object and "patient" to the subject position. The sentence-level representations themselves depend on syntactic categories, since relations like subject and object require knowledge of the categories noun and verb. If young children can parse sentences into hierarchical sequences of abstract syntactic units, their early sentence-level productions should reflect that knowledge.

Evidence from observational studies of children's productions suggests that English speaking 2-year-olds represent some of the syntactic properties of the building blocks—syntactic categories like noun, noun phrase, determiner, preposition, and prepositional phrase (Valian, 1986; for the determiner, Valian, Solt, & Stewart, 2008, and references therein; Kemp, Lieven, & Tomasello, 2005, for suggestions that early representations of determiners are partially abstract) and some of the properties of the concept "syntactic subject" (Valian, 1991; see Tomasello, 2000a for conclusions to the contrary). There is continuing debate about how native speakers represent clause-level constructions, both in child language processing (Fisher, 2002; Tomasello, 2000a, 2000b) and adult language processing (Bencini, 2002; Bencini & Goldberg, 2000; Bock, 1986; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Chang, Bock, & Goldberg, 2003; Goldberg, 1995; Goldberg & Bencini, 2005).

Support for lexically specific, verb-centered, sentence representations exists in both observational and experimental studies of verb production. In spontaneous speech, children use verbs conservatively: they seldom produce a verb in a sentence structure in which they have not heard it used before. In many elicited production experiments with nonsense verbs, 2- to 3-year-olds have failed to transfer novel verbs acquired in an intransitive structure (e.g., *The sock is tamming*) to a transitive structure (e.g., *The cat is tamming the sock*) (Childers & Tomasello, 2001; Lieven et al., 1997; Olguin & Tomasello, 1993; see Tomasello, 2000b for a review), suggesting that children's early verb use closely mirrors the input. This seemingly strict adherence to the input is consistent with the view that early on children do not possess verb-general argument structure constructions, but operate with lexically bound generalizations either around verbs (the Verb Island Hypothesis, Tomasello, 1992), pronouns (Childers & Tomasello, 2001), or frequent noun phrase–verb combinations (McClure, Lieven, & Pine, 2006).

More recently, the technique of syntactic priming, first used with adults (Bock, 1986; Bock & Loebell, 1990), has been adapted to address representational questions with children (Savage, Lieven, Theakston, & Tomasello, 2003). Syntactic priming exploits the tendency of participants to re-use sentence structures they have encountered earlier, even in the absence of lexical or conceptual overlap between the priming sentences and the targets. In adults, the occurrence of priming between sentences that share structure but not content words is evidence for a stage in language production that is dedicated to building sentence structure independent of lexical content (Bock & Loebell, 1990). Priming is enhanced when there is lexical overlap (Pickering & Branigan, 1998), but adults also show pure structural priming. Previous syntactic priming studies with young children have led many to conclude that 3-year-olds' grammars lack the levels of abstract representation required to support priming of the passive (Savage et al., 2003—3- to 5-year-olds), though older children's grammars contain them (Huttenlocher, Vasilyeva, & Shimpi, 2004—4- to 5-year-olds; Savage et al., 2003—6-year-olds), but see a recent report of priming in 3-year-olds under certain conditions (Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007).

At the same time, however, some comprehension studies show that 2-year-olds use structural cues such as word order to assign meaning to novel verbs, supporting claims for Early Abstraction (Fernandes, Marcus, DiNubila, & Vouloumanos, 2006; Fisher, Hall, Rakowitz, & Gleitman, 1994; Gertner et al., 2006; Naigles, 1990; Naigles, Bavin, & Smith, 2005). Thus, the existing data on young children's sentence comprehension and production could support a view in which the child relies on lexically specific sentence representations in production but abstract ones in comprehension (Fernandes et al., 2006; Fisher, 2002). Since no extant studies have compared production and comprehension, it has been impossible to evaluate that possibility (although a recent computational model by Chang, Dell, & Bock, 2006, attempts to reconcile comprehension–production differences). For that reason, we examine children's performance with the same syntactic structure—the passive—on both sentence production and comprehension tasks.

Passives, especially full passives that include both the subject and object (e.g., *The rabbit is chased by the goose*), are extremely rare in spoken English and in child-directed speech. In the 4 million word corpus of spoken British English (Aston & Burnard, 1998) the percentage of full passives is .00007 ($n = 290$); the percentage of all passives (both full and truncated, containing either the auxiliary *be* or *get*) is .001 ($n = 6301$; Table 3 in Xiao, McEnery, & Qian, 2006).

In 86,655 adult input sentences to 3 children aged 2–5 (Brown, 1973), the rate of occurrence of full passives was .00005 ($n = 4$), for truncated passives it was .001 ($n = 87$), and for adjectival passives it was .002 ($n = 197$; Gordon & Chafetz, 1991). The paucity of passives in such large databases lends confidence to the conclusion that children rarely hear passives. Their absence is not a sampling issue (Tomasello & Stahl, 2004). Passives are also extremely rare in 4-year-olds' speech (Huttenlocher et al., 2004). In 90-min spontaneous speech samples of 12 four-year-olds who scored in the top quartile of a syntax comprehension test, there were no full passives. Two children produced one truncated passive each; two children produced truncated passives with only one verb (Huttenlocher et al., 2004, based on data from Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002).

Rarely heard and produced structures are likely to be pragmatically marked, hard to process, or both. We propose that rarity in the input—rather than an inability to construct sentence-level representations or generate passives via adult-like syntactic operations (e.g., Borer & Wexler, 1987, 1992)—is the source of the absence of passives in English-speaking children's speech. Children seldom produce passives because they are not part of conversational speech. Consistent with our hypothesis, where passives are frequent in the input, as in Sesotho, children produce passives before age 3 (Demuth, 1989).

Our threefold goal in this paper is (1) to determine whether 3-year-olds exhibit abstract priming with passives, (2) to establish the relation between comprehension and short-term priming in production, and (3) to examine whether learning occurs during priming. We discuss each goal in turn below.

To determine the abstractness of children's representations, we use a syntactic priming task. Previous syntactic priming studies have failed to find abstract priming—priming across sentences that do not share content words (nouns and verbs)—in 3-year-olds. In a study with 3-, 4-, and 6-year-old children, Savage et al. (2003) primed children with active and passive sentences and asked children to describe new pictures with different nouns and verbs. Whereas 6-year-olds showed priming even when the prime and the target were lexically different, 3- and 4-year-olds showed priming only when the prime and the target overlapped lexically, that is, only when the experimenter said a prime with pronouns that the child could re-use in his or her target description (E: It pushed it, C: It cut it).

Younger children's representations of verb argument structure are not completely verb-centered, since children were primed with different verbs from the ones they used in the target descriptions. The results might thus support the existence of a developmental stage of generalization around lexical "islands"—either pronouns (Childers & Tomasello, 2001) with open verb slots (e.g., *It is VERB-ing it*, *It is VERB-en by it*), or frequent noun phrases around verbs (McClure et al., 2006).

Another possibility, however, is that the cognitive demands of the task mask younger children's abstract representations. When 3-year-olds hear priming sentences in a block and do not repeat them, they do not show priming of the passive. When 3-year-olds do repeat priming sentences, they show priming of the passive, although almost half of the passives are truncated (Shimpi et al., 2007). Accordingly, while we require "classical" evidence of abstract priming here, we also take pains to reduce the processing of features peripheral to the task of sentence generation, such as lexical look-up. Classical evidence requires (a) stimuli with full noun phrases and (b) stimuli with no repetition of verbs. Our stimuli and procedures follow those requirements. To reduce the demands associated with lexical look-up, we include a lexical warm-up phase before the priming trials to familiarize children with all the nouns and verbs.

Recently, studies with adults (Bock, Dell, Chang, & Onishi, 2007) and 4- to 5-year-old children (Huttenlocher et al., 2004) have found priming effects in production whether the participant only hears the prime before describing a target picture (comprehension-to-production priming) or both hears and repeats it (comprehension + production-to-production priming). Both adult and child studies have found long-lasting priming and similar magnitudes for both types of priming. The existence of comprehension-to-production priming suggests a closer relationship between the processes of comprehension and production than previously assumed in psycholinguistics (Bencini, 2002; Bock, 1995; Clark & Malt, 1984). It also suggests that priming taps into linguistic representations that are shared between comprehension and production (Bencini, 2002; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995). The extent of the relationship, however, remains unknown.

Our second goal is thus to examine the relation between children's performance on comprehension and production. Production-to-comprehension priming has been difficult to demonstrate, even in adults, typically occurring only when there is overlap of verbs (Branigan, Pickering, & McLean, 2005). To determine possible effects of production on comprehension, we test children's comprehension in a single session both before and after priming. We use a forced-choice comprehension task with fully reversible passive sentences with animate agents and patients. In previous picture selection tasks with reversible passives and actional verbs, children have performed reliably above chance starting at 42 months (Gordon & Chafetz, 1991; Stromswold, Eisenband, Norland, & Ratzan, 2002). Comprehension of passive sentences by younger children, however, has not been demonstrated.

Finally, we examine whether priming might be a form of learning (Bock & Griffin, 2000; Chang et al., 2006). It is possible both that some 3-year-olds already have a representation of the passive and that other 3-year-olds have some of the building blocks (e.g., syntactic categories and relations) but have not put all the pieces together. The combination of exposure to passive sentences and practice in repeating them might help children put the pieces of the passive together. By comparing children's performance during the first and second half of priming, we can determine whether any learning has taken place.

In summary, this study has three goals: (1) to determine whether 3-year-olds exhibit abstract priming with passives, (2) to compare children's performance in a forced-choice comprehension task with their performance in priming, (3) to determine whether learning occurs during priming.

Method

Participants

Participants were 53 monolingual English-speaking children (30 females), with middle- to upper-middle-class parents, ranging in age from 2 years 11 months (2;11) to 3;6, with a mean of 3;2. An additional 43 children were tested but their data were excluded because of failure to follow instructions or uncooperativeness ($N = 28$) or failure to meet general criteria for inclusion in the study, such as age, first language, or distracting conditions during testing ($N = 15$). The children are thus "young" 3-year-olds. Of the 28 children who met inclusion criteria but whose data were excluded, 25 completed the first part of the first experimental session—lasting approximately 20 min—that tested their comprehension of reversible passives. The experimenter stopped the session when the child showed signs of lack of interest or fussiness. At the first sign of fussiness, the experimenter asked the child whether she wanted to continue playing the game, and if the child said she did not or showed lack of interest (e.g., by walking away) the experimenter stopped the session. Children were recruited through mailing lists, daycare centers, and personal contacts. They participated at home, in the laboratory, or at daycare. Children participated in one of three groups: passive priming ($N = 18$), active priming ($N = 18$), or no priming (control, $N = 17$).

Experiment overview and design

Experimental children were tested twice; control children were tested once. Table 1 outlines the experiment. For experimental children, Session 1 was approximately one hour in length and consisted of two comprehension tasks sandwiching a production (priming) task. The first comprehension task measured children's initial comprehension of 8 fully reversible passives with animate agents and animate patients. The priming task primed actives for one group and passives for another group. After priming, the second comprehension task measured children's performance on 8 new reversible passives. Session 2 was approximately 25 min in length and occurred roughly 2 weeks after the first session (average 15 days, range 12–35); it measured long-term comprehension of reversible passives with 8 new and 8 old sentences.

Table 1
Overview of experiment

Session 1
Initial comprehension
All groups—8 fully reversible passives with pictures
Priming
Active group—8 active primes with pictures alternating with 8 target pictures
Passive group—8 passive primes with pictures alternating with 8 target pictures
Baseline group—8 target pictures only
Short-term comprehension
Active and passive groups—8 new fully reversible passives with pictures
Session 2
Long-term comprehension
Active and passive groups—16 fully reversible passives with pictures (8 old items, 8 new items)

In priming, each experimental child heard and attempted to repeat either 8 active or 8 passive sentences describing pictured transitive events with inanimate participants (e.g., *The wagon is carrying the presents* or *The presents are carried by the wagon*) and described 8 target pictures of different transitive events with inanimate participants (e.g., a picture of a knife slicing a lemon). Repetition and description alternated: the child repeated a priming sentence and then described a different picture.

For control children the procedure was slightly different. Control children participated in the initial comprehension task but did not perform the repetition task. Instead, each baseline child saw only the 8 target pictures and attempted to describe them. Priming condition (active, passive, control) was thus a between-subjects manipulation.

Assignment of children to condition was quasi-random in an effort to equalize age and baseline comprehension score across conditions. As it happened, 5 children who were assigned to the control condition had unusually low comprehension scores (mean correct = 2.4/8; range 2–3). Those children were included in the comprehension data analysis ($N = 17$), but they were excluded from the production data analysis ($N = 12$) to ensure that their low comprehension would not affect estimates of the production of passives in the absence of a prime.

Comprehension procedure and materials

For all children, the comprehension task was preceded by a lexical warm-up phase that introduced each of the 16 characters who were later displayed in the comprehension pictures, 4 to a page. Children were asked to name the items and, if they did not name all the items, the experimenter asked the child to point to the *x*. Lexical warm-up also served to engage the child and build rapport. Within the comprehension

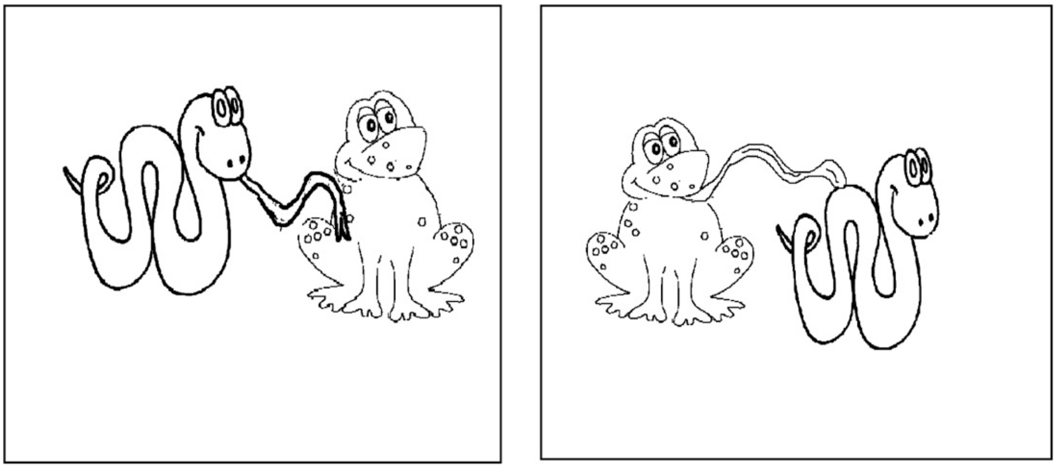

Fig. 1. Sample comprehension trial.

task itself, on each trial, the experimenter first had the child identify the characters in the two pictures. Fig. 1 presents an example of a comprehension trial. The experimenter introduced each picture set by naming both animal characters. For example, she might say, "There is a frog in both pictures, and there is a snake in both pictures." She then asked the child to point to each character by saying, "Can you point to the frog in both pictures? Can you point to the snake in both pictures?" After the child had correctly pointed to each character, the experimenter said, "In one picture, the snake is licked by the frog; which one?" After the child pointed, the experimenter said, "Put a sticker on that page." Sticker placement was used to increase the children's enjoyment, since they loved manipulating the stickers.

The comprehension materials were 24 pairs of pictures of reversible transitive events (e.g., a picture of a cat brushing a dog, and a picture of a dog brushing a cat). For all children, the events were always described with a full passive (e.g., *The cat is brushed by the dog*) and children were asked to point to the picture corresponding to the description. All the characters were animate and most were animals. Each picture depicted a different action. The materials were arranged in a binder, with each picture from an item pair printed in color on a separate page in portrait format. Twenty-four different regularly-inflected verbs, selected from other 2-year-olds' spontaneous speech, were used to describe the pictures. Across experimental children the order of presentation was counterbalanced such that each picture pair appeared an equal number of times in the baseline, short-term, and long-term phase. Across pairs of pictures the agent of the action was on the left half the time. For the control condition, children's comprehension was tested only during the initial phase. Each correct choice appeared an equal number of times on the left and the right across trials.

Priming procedure and materials

After the initial comprehension task, we told experimental children that they would now look at a different picture book and would play another game where "we take turns saying things about pictures". We again had a lexical warm-up to help the child recognize the objects and actions depicted in the priming pictures. Separate procedures were used for the nouns and the verbs. In the noun warm-up, children were asked to name each object used in the priming picture and in the target picture. The objects were presented in isolation, 4 per page, with no action inferable from the picture. All 32 objects were presented.

For the verb warm-up, reduced-size black and white copies of the priming and target events were presented, 4 per page. The experimenter introduced the verb identification task by telling the child to "look at what's happening in these little pictures!" Then the experimenter described an action using a verb in the gerund and asked the child to find the corresponding picture (e.g., "Can you show me dumping? Where is dumping?"). All of the children tested understood the task and in general had no trouble identifying the actions.

Pilot testing ($N = 30$) revealed that it was optimal to interleave the verb warm-up and the priming task so that one page of 4 verb warm-ups preceded 2 priming blocks (i.e., 2 sets of alternating repetition primes and descriptions of targets).

On each priming trial, the experimenter described the priming picture in the active for one group and the passive for another group and asked the child to repeat the sentence. Then the child was shown a new picture (the target) and was asked to describe it. Fig. 2 shows the sequence of events for one priming block. Control children heard no priming sentences but did receive

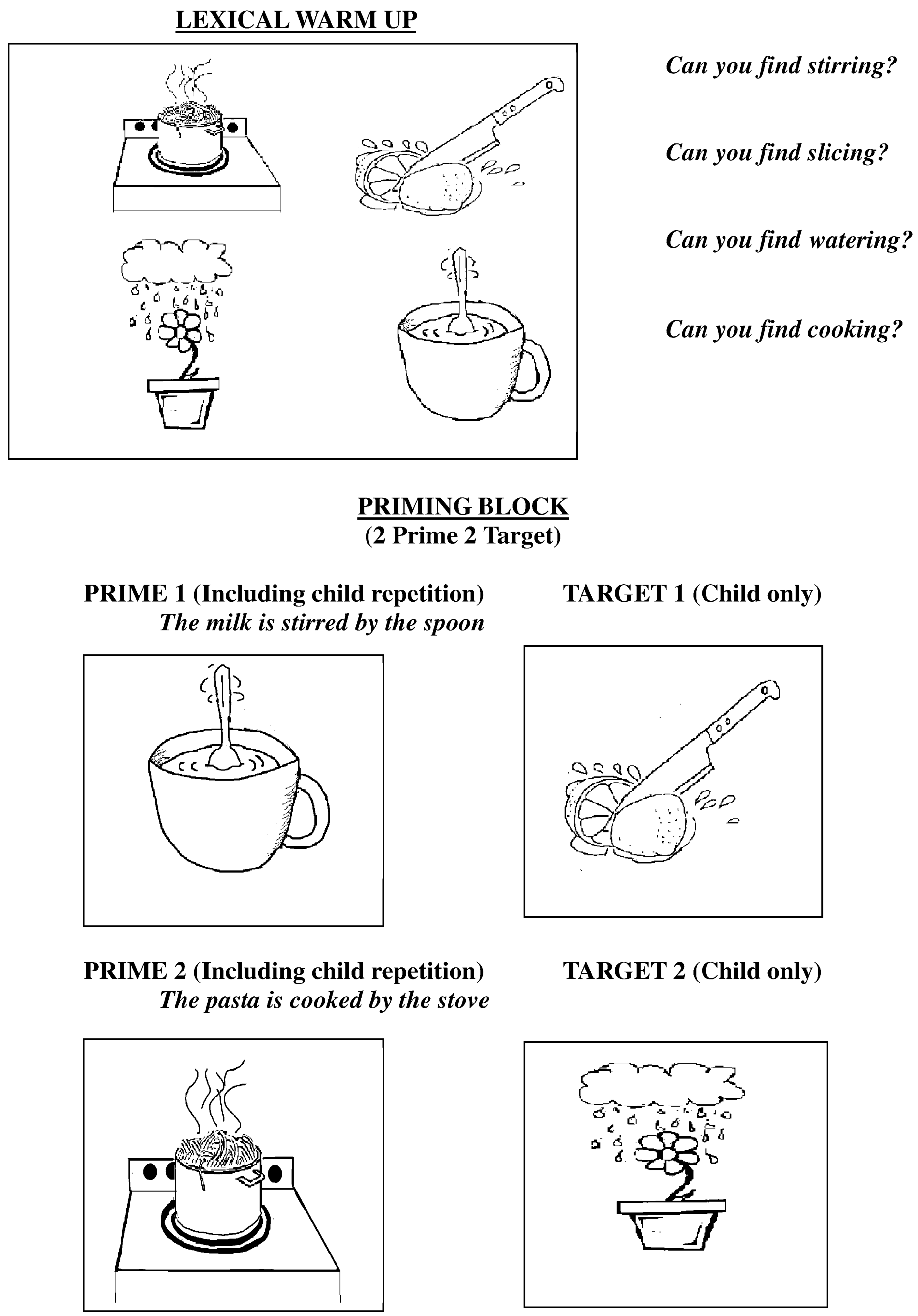

Fig. 2. Sample verb warm-up and priming block.

noun and verb warm-ups for the pictures they had to describe.

There were 16 colored drawings of transitive events that could be described either with active or passive sentences. All of the pictures depicted action scenes with inanimate agents and inanimate patients (e.g., a picture of a wagon carrying presents, a picture of water filling up a glass) and were non-reversible. Inanimate agents and patients were used for two reasons. First, to ensure that structural relations rather than conceptual features such as animacy are being primed, it is necessary to use either animate–animate or inanimate–inanimate pairs. Second, since the comprehension task demanded reversible animate–animate passives and we did not want to re-use any verbs, we restricted the stimuli to inanimate–inanimate pairs.

Eight drawings accompanied priming sentences and 8 served as targets for the children to describe. Across children, each prime–target pair was used in both active and passive conditions. To ensure that priming, if it occurred, would be abstract, no verbs were ever repeated and no actions were repeated from picture to picture. The priming pictures and the targets were balanced for orientation of the agent relative to the action. There were an equal number of pictures with the agent on the left and an equal number where orientation was neutral on the horizontal axis. The active sentence primes were in the present progressive (e.g., *The wagon is carrying the presents*). The passive sentence primes contained the auxiliary *be* and were in the simple present (e.g., *The presents are carried by the wagon*). A list of the materials is provided in the Appendix.

The experimental sessions were audio-recorded with an Olympus DSS digital audio recorder. A digital file for each child consisting of that child's 8 descriptions of the priming pictures was created by excising the portion of the file where the experimenter produced the prime sentence and asked the child to repeat it. Children's descriptions of the target pictures were transcribed by one experimenter and checked by at least one other person. Both transcriber and checker were blind to priming condition (active, passive, no priming control). Children's repetitions of the priming sentences were transcribed by one experimenter and completely checked by at least one other person. The transcriber and the checker reviewed the transcriptions together to reach an agreement on the final version.

Scoring of repetition

Across children there were eight passive and eight active priming sentences to be repeated, producing a total number of 288 to-be-repeated sentences. Four priming sentences were not repeated, two in the active (one child) and two in the passive (two children), so that 142 passive and 142 active sentences were scored for repetition.

Verbatim repetitions were defined as the proportion of primes that the child repeated correctly, whether active or passive, including inflectional morphology (*be* for the active progressive and the passive, *-ing* for the active progressive, *-en* for the passive, and *by* for the passive). Substitutions of nouns or verbs were not allowed, only substitutions or omissions of determiners (e.g., *a wagon* or *wagon* instead of *the wagon*). *Constituent repetitions* were defined as the proportion of primes that the child repeated that included both arguments and the verb, whether or not inflectional morphology was present. Again, substitutions were not allowed.

Scoring of priming

Children rarely failed to describe a picture ($n = 2$). The experiment thus produced a total of 382 descriptions (18×8 in each of the two priming conditions plus 12×8 for the no priming control condition minus 2 skipped trials). Descriptions were scored for syntactic form as *active*, *passive*, or *other*. Scoring was done by two coders, blind to condition. Inter-coder agreement was high (>98%) and disagreements were resolved through consultation.

There is no consensus in the child priming literature as to how priming should be scored. Here we use three scoring schemes modeled on existing child and adult priming studies. We will refer to them as lax coding, strict coding, and adult coding. The schemes differ from one another on three dimensions: (1) whether they include descriptions from trials where the priming sentence was not repeated correctly; (2) what counts as an active or passive description; (3) whether the dependent measure for priming—the probability of producing a description in one of two alternating structures (active, passive)—is computed over the alternating structures (actives + passives) only, or over all structures (actives + passives + others). The lax and strict coding schemes allow us to compare our results with previous priming studies with young children; the adult scheme allows us to compare the results with adult priming studies.

The dependent measures for priming in the lax and strict coding schemes were the proportion of active and passive descriptions out of the total number of descriptions produced (active + passive + other; Huttenlocher et al., 2004). For example, if a child produced 1 *passive*, 2 *actives* and 5 *other* descriptions, the denominator was 8 and the child's passive score was .13. For the items analysis, if a picture was described with 4 *passives*, 4 *actives*, and 40 *others* in one cell of the design, the denominator was 48 and the item's passive score was .08.

The lax and strict coding schemes code all target trials (picture descriptions), irrespective of how successfully the child repeated the earlier priming sentence. This deviates from procedures in the adult literature that require the priming sentence to be repeated correctly; we believe that it is desirable to score all trials with young children, since they are much less likely than adults to correctly repeat the priming sentences. For lax and strict scoring, there were 382 scoreable productions: 143 in response to active primes, 144 in response to passive primes, and 95 in the no priming (control) condition. For adult scoring, in contrast, there were 162 scoreable productions (from 29 children, 15 of whom received active priming) out of 382 (42%).

Lax coding

Target descriptions were scored as *active*, *passive*, or *other*. Actives required: (a) the agent of the action in subject position, followed by (b) a transitive verb optionally preceded by a form of *be* or *have*, optionally followed by (c) a direct object (Huttenlocher et al., 2004). Examples are: *the truck is dumping*; *the knife is cutting*; but not *the car is going*. Passives required: (a) the patient in subject position, followed by (b) the main verb optionally preceded by a form of *be* or *get*, optionally followed by (c) the agent or instrument of the action within an adjunct phrase headed by the preposition *by* or *with*. Thus, truncated passives were allowed (Huttenlocher et al., 2004). Examples are: *the car is towed; the ice cream is melted*. Passives with uninflected verbs were also accepted, but passive-like descriptions with the incorrect inflection were not. For example, *the ice cream is melt by the sun* would be scored as a passive, but *the ice cream is melting from the sun* would not.

Strict coding

To be scored *active*, a description had to include the same elements as in lax coding, plus the patient of the action in the direct object position. To be scored *passive*, a description had to include the same elements as in lax coding, plus the agent or instrument of the action within an adjunct phrase headed by the preposition *by* or *with*.

Adult coding

Following procedures in the adult priming literature (Bock, 1986; see also some child studies, e.g., Savage et al., 2003), we excluded target descriptions where the child failed to repeat the immediately preceding priming sentence correctly, i.e., all trials where the repetition of the prime was not verbatim. Strict scoring was used.

We also excluded trials where the child produced a description other than an active or passive, following the adult priming literature which computes proportions of target structures over the sum of descriptions that have a structural alternative (Bock, 1986): the denominator was the number of transitive descriptions (active + passive). For example, if a child produced 1 *passive*, 2 *actives*, and 5 *other* descriptions, the denominator was 3 and the child's passive score was .333. Similarly, for the items analysis, if a picture was described with 4 *passives*, 4 *actives*, and 40 *others* in one cell of the design, the denominator was 8 and the item's passive score was .5. The use of adult coding allows a comparison of effect sizes with adult findings. Of the 162 scoreable responses, 86 (from 9 children) were scored *other*, leaving a total of 76 passives and actives (40 descriptions from 10 children who received active priming and 36 from 10 children who received passive priming) that could enter into the adult-type data analysis.

Analyses

The experiment produced three dependent measures: priming of passives, repetition accuracy, and comprehension. We have already described the priming measure. Repetition accuracy was defined as the proportion of active and passive priming sentences repeated correctly out of the total number of repetitions attempted (typically 8 per child). Comprehension was measured as percentage of correctly selected pictures.

For priming, repetition, and comprehension, separate analyses were performed treating participants (F_1) and items (F_2) as random effects. Although we made a directional prediction for priming (that passives and not actives would prime passives), for ease of computation and presentation of confidence intervals and minF', two-tailed tests are presented. Statistical analyses were also performed on the arcsine transformed proportions of responses (Bock & Griffin, 2000), which produced the same pattern of results as analyses of raw proportions. We present statistics on raw proportions because they are easier to interpret than arcsines (Studebaker, 1985). All proportions are computed with unweighted means. For differences between means, we report the 95% confidence intervals (CIs) taking the mean squared errors from the participants analyses (Masson & Loftus, 2003).

Results

Our principal prediction was that 3-year-olds would represent sentences abstractly, rather than organize them around individual verbs, and thus would exhibit abstract structural priming. We thus first report children's success in producing descriptions to new target pictures with inanimate agents and patients. We then report children's success in repeating priming sentences that described pictures with inanimate agents and patients, and in comprehending descriptions of pictures with animate agents and patients before and after the priming task.

Priming

Table 2 shows the overall proportions of *active*, *passive*, and *other* descriptions produced in the active, passive, and no priming (control) conditions, according to strict and lax coding schemes. As can be seen from Table 2, control children produced no passives, whether coding was strict or lax.

Lax coding

Children produced more lax passives after passive primes than after active primes (23/144, 0.16 vs. 3/143, 0.02; $F_1(1,34) = 7.85$, $p < .01$; $F_2(1,7) = 13.08$, $p < .01$, $\min F'(1,32) = 4.91$, $p < .04$; 95% CI for the 0.14 difference between means was $\pm.1$).

Children who received passive primes produced more passives in the second half of the trials than in the first half (17/144, 0.24 vs. 6/144, 0.08; $F_1(1,17) = 8.00$,

Table 2
Mean percentage (%) of children's utterances scored as *actives*, *passives*, or *other* in each priming condition according to strict and lax scoring criteria

Priming condition	Children's utterance type					
	Strict scoring			Lax scoring		
	Active	Passive	Other	Active	Passive	Other
Active ($N = 18$)	36	2	62	38	2	60
Passive ($N = 18$)	33	11	56	35	16	49
No priming ($N = 12$)	22	0	78	33	0	67

Note: Percentages are computed with total number of descriptions in the denominator (*active* + *passive* + *other*).

$p < .02$; $F_2(1,6) = 15.29$, $p < .01$; $\min F'(1,22) = 5.25$, $p < .04$; 95% CI for the 0.16 difference between means was ±.15). Children produced numerically more actives after active primes than after passive primes (54/143, 0.38 vs. 51/144, 0.36), but this difference was not significant by subjects or items (Fs < 1). Out of the 23 lax passives, 5 were truncated, 2 had the preposition *with*, one had *from*, and the rest had *by*.

Strict coding

Children produced more strict passives after passive primes than after active primes (16/144, 0.11 vs. 2/143, 0.02; $F_1(1,34) = 3.78$, $p < .07$; $F_2(1,7) = 7.28$, $p < .04$); $\min F'(1,34) = 2.49$, n.s.; 95% CI for the 0.09 difference between means was ±.09; 90% CI for the difference—reflecting our directional prediction—was ±.07.

Children who received passive primes produced numerically more passives in the second half of the trials than in the first half, but this difference was only marginally significant by subjects and not significant by items (12/144, 0.17 vs. 4/144, 0.06; $F_1(1,17) = 3.6$, $p < .08$; $F_2(1,6) = 4.1$ $p < .09$; $\min F'(1,19) = 1.92$, n.s.; 95% CI for the 0.11 difference between the means ±.14). Children produced numerically more strict actives after active primes than after passive primes, but the difference was not significant either by subjects or by items (51/143, 0.38 vs. 47/144, 0.33, Fs < 1). Out of the 16 passives, 2 had the preposition *with*, all the others had *by*.

Adult coding

In the adult coding scheme children's descriptions of the target sentences were included only if they followed correct repetition of the priming sentence; the dependent variable was the proportion of primed descriptions (active or passive) out of the number of transitives (*actives* + *passives*). Application of these criteria excluded data from 8 children from each priming condition because they repeated no priming sentences correctly; for the remaining 20 children it also excluded trials where the child had not repeated the prime. Those 20 children produced more passives after passive primes than after active primes (16/36, 0.42 vs. 3/40, 0.09; $F_1(1,18) = 4.91$, $p < .04$; $F_2(1,7) = 13.68$, $p < .01$; $\min F'(1,25) = 3.61$, $p < .07$; 95% CI for the 0.33 difference between the means was ±.32). (Results for the active, for this comparison only, are the complement.)

Priming summary

With both lax and strict coding, 3-year-olds showed abstract priming of the passive but not for the active (either lax or strict). The magnitude of the priming effect for passives (14 percentage points or 9 percentage points for lax or strict coding, respectively) is comparable to what has been reported for slightly older children (14% in Huttenlocher et al., 2004, who used lax scoring). With adult scoring, which excludes incorrectly repeated trials and non-transitives, the magnitude of passive priming is much larger (42%–9%, or 33 percentage points) than that found in adult studies (between 5 and 10 percentage points, depending on the study, Chang et al., 2006). With adult coding, active priming was also significant. There was some evidence for the build-up of passive priming over trials, with more passives occurring in the second half of the trials, but this difference was only significant for passives scored via the lax coding scheme.

The effective component of passive priming was having the children hear and repeat the priming sentence before describing a new picture. The comprehension task did not promote priming (Shimpi et al., 2007). That is evident from the complete absence of a priming effect for passives for the control children, who heard the comprehension sentences but did not receive priming sentences.

Performance across subjects

Passives were produced by 2 of the 18 children who received active priming and by 6–9 of the 18 children who received passive priming (depending on coding scheme). Actives were produced by 8–12 of the children who received active priming and by 8–16 of the children who received passive priming. Those numbers probably underestimate children's susceptibility to abstract priming, since they do not adopt the precondition for priming used in adult studies—that at least one of the

2 structural alternatives occur in each cell of the design. In our study, 9 children never produced any transitive descriptions—active or passive, a disinclination which may have resulted from the verb warm-up procedure where we described each target picture with the gerund (e.g., *Here is cracking*). A better estimate of priming of the passive across subjects can thus be achieved by including only children who produced at least one transitive description.

Fig. 3 displays each child's proportion of passives produced in priming and understood in comprehension. The top panel represents children primed with actives and the bottom panel represents children primed with passives. The black bars represent proportion passives via strict coding, the stack consisting of the black bars and the white bars represents proportion passives via lax coding, and the total stack represents proportion passives via adult coding. The filled circles represent the proportion of comprehension sentences correctly responded to.

Lax coding

Thirty children (14 in the active priming condition and 16 in the passive priming condition) produced at least one lax transitive description. Passives were produced by 2/14 (14%) children in the active condition and by 9/16 (60%) children in the passive condition. Five children produced one passive, three children produced 3, one child produced 4, and one child produced 5 passives.

Strict coding

Twenty-eight children (12 in the active priming condition and 16 in the passive priming condition) produced at least one transitive description. Passives were produced by 2/12 (20%) children in the active condition and 6/16 (40%) children in the passive condition. Two children produced 1 passive, two children produced 3, and two children produced 4 passives.

Adult coding

Exclusion of trials with incorrect repetition resulted in inclusion of 10 (60%) children in the active priming condition and 10 (60%) children in the passive condition. Passives were produced by 2 of the 10 (20%) children in the active condition and 8 of the 10 (80%) children in the passive condition. Two children produced 1 passive, two children produced 3, and two children produced 4 passives.

In summary, abstract priming of the passive in young 3-year-olds appears to be general. Priming was observed between 40% and 60% of children who produced at least one transitive description. The use of gerunds in the warm-up task may have biased some children against producing transitives. Of those who did produce transitives, priming was common.

The adult scheme excludes additional children who did not correctly repeat the priming sentence. Although this criterion is standard in the adult literature, it may be inappropriate for children, since repetition taxes the child's processor more than the adult's. Children who are able to repeat the priming sentences correctly with one exposure may be more advanced, or have greater processing abilities, or perhaps be unrepresentative of the population. With the adult scheme, however, 80% of the children show abstract priming of the passive.

Use of pronouns in active and passive descriptions

To further test for abstractness, we examined children's use of pronouns, since pronouns might provide children with a partially-filled lexical template that they could re-use across descriptions. For example, the child may say, "it is broken by it" and "it is filled by it". On the first occurrence of a pronominal description ("it is verb-ed by it") priming would be abstract because the priming sentences contained full NPs and not pronouns.

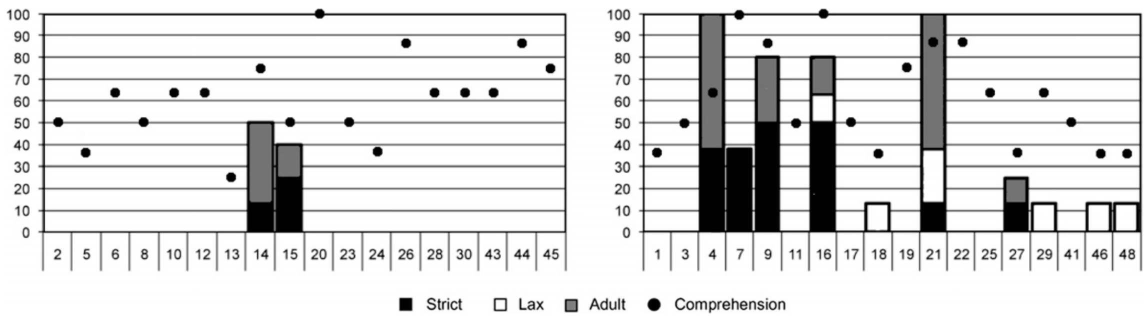

Fig. 3. Display of each child's proportion of passives produced in priming and understood in comprehension. The left panel represents children primed with actives and the right panel represents children primed with passives. The black bars represent proportion passives via strict coding, the stack consisting of the black bars and the white bars represents proportion passives via lax coding, and the total stack represents proportion passives via adult coding. The filled circles represent the proportion of comprehension sentences correctly responded to.

If, however, a child continued re-using descriptions with pronouns on subsequent trials, as a result of self-priming, that priming would be partly lexical, triggered by the repetition of pronoun islands, as in Savage et al. (2003), with 3- to 4-year-olds. Such a lexically-filled schema is less abstract than a fully productive description with different noun phrases and may correspond to an intermediate level of generalization found in gradualist and lexicalist accounts of acquisition (McClure et al., 2006).

We accordingly computed the frequency of pronouns as agents or patients in strict descriptions of the target pictures. For example, *the knife is cutting it* and *we are cutting it* were both scored as pronominal even though the first sentence contains only one pronoun and the second sentence contains two. Of the 134 strict transitive descriptions (active and passive) produced by children across all three conditions, 18 (13%) contained one or more pronouns. All 18 occurred in active descriptions. Children who produce passives as a result of passive priming do not do so by setting up a pronoun template.

Classification of other descriptions

There were 194 *other* descriptions (i.e., neither passives nor actives) in the lax coding scheme. Table 3 classifies those descriptions by type of constituent included. There were no differences in the numbers of types of non-transitive descriptions between the two priming groups, demonstrating that the two groups of children operated with roughly equivalent conceptual representations and that the differences in their picture descriptions were due to the syntax of the priming sentence (Bock, 1986). For single constituent descriptions (e.g., *A crayon*) and intransitive sentences with a subject (e.g., *The icecream is melting*) we also looked at whether there were differences across conditions in mention of the agent or the patient of the event in the picture. There were no differences across priming conditions.

The single difference in the descriptions produced by children who received active vs. passive primes was that the former produced numerically more descriptions that consisted solely of a verb or a pronoun plus verb (e.g., *watering*, *it's cracking*). Those children had heard twice as many *-ing* forms as children who received passive priming (due to the verb warm-up phase which used gerunds), a difference that may have created a sublexical priming effect.

Table 3
Child productions scored as *other* in the lax coding scheme, separated by type

Priming condition	Production type			
	Subject + verb	Verb only	Noun only	Miscellaneous
Active ($N = 18$)	14	43	9	8
Passive ($N = 18$)	14	27	6	5
No priming ($N = 12$)	4	38	19	7

Repetition

We examined the children's ability to repeat passives and actives in two ways, via verbatim repetitions or via constituent repetitions (repetitions of the three major constituents). Since the passive contains more morphology than the active and is thereby longer, the constituent repetition measure neutralizes that difference. The number and percentage of verbatim and constituent repetitions to active and passive primes is shown in Table 4. As can be seen, children produced *verbatim* repetitions more often to active than to passive priming sentences (0.71 vs. 0.43; $F_1(1,34) = 4.52$, $p = .04$; $F_2(1,7) = 48.96$, $p < .0001$; $\min F'(1,39) = 4.12$, $p < .05$; 95% CI for the 0.28 difference between the means was ± 0.27). There were no differences in children's verbatim repetitions between the first and second half of the trials. Children showed a slight tendency to produce *constituent* descriptions more often to actives than to passives (0.82 vs. 0.71; $F_1(1,34) = 1.1$, n.s; $F_2(1,7) = 8.9$, $p = .02$; $\min F'(1,40) = .98$, n.s.).

To determine the locus of repetition differences between actives and passives, we examined the inclusion rates of the constituents and morphemes in each sentence type. For the active they included: NP1, auxiliary, verb stem, progressive morpheme (*-ing*), and NP2. For the passive they included: NP1, auxiliary, verb stem, past participle morpheme (*-en*), *by*, and NP2. Inclusion rates for NPs and verb stems were computed for all non-verbatim repetitions. Inclusion rates for auxiliaries and inflections were computed only for non-verbatim repetitions that contained at least the verb root. There were 49 (0.60) *non-verbatim* passive repetitions and 33 (0.80) *non-verbatim* active repetitions containing a verb root. The mean number and proportion constituent inclusion rates are shown in Table 5.

Because the large number of empty cells precludes statistical analysis, we make only two cautious observa-

Table 4
Repetition results: number (and percent) of *verbatim* and *constituent* repetitions to active and passive primes

Priming condition	Repetition form	
	Verbatim	Constituent
Active ($N = 18$)	101 (71)	116 (82)
Passive ($N = 18$)	60 (42)	99 (71)

tions. (1) The children appeared equally likely to mention the patient in the two conditions—expressed as surface subjects in the passive (NP1, 0.93) and surface objects in the active (NP2, 0.82). But children were more likely to mention the agent in passives (0.96) than in actives (0.46), possibly a recency effect. (2) Among the non-verbatim repetitions containing a verb, the progressive morpheme was included twice as often as the passive morpheme, possibly reflecting lexical priming from the warm-up phase, where all of the verbs (prime and target) were first introduced in the gerund.

Comprehension

We computed two different measures of comprehension. The first, used in this analysis, compared the children as a group against chance, which was 50% or 4/8. The second, used in the next section, analyzed for each child whether he or she was above chance (7/8 or 8/8). Taken as a whole, and including those 5 children with low comprehension scores who were excluded from the control condition for the purposes of the priming data analyses, children were above chance (.50) on comprehension of reversible passives. At baseline, prior to assignment to condition, children scored 4.6/8 (0.58) correct responses ($t_1(52) = 2.79$, $p < .01$; $t_2(23) = 2.4$, $p < .03$; 95% CI of the difference from chance was $\pm.05$). Children's comprehension of passives did not improve after priming with passives. There were no differences either over time or by priming condition in success at comprehension: at each measuring point children were, on average, significantly above chance. Children who received active primes (18) averaged 4.9/8 (0.61) correct responses on the initial test, 5.3/8 (0.66) on the short-term test, and 10.4/16 (0.65) on the long-term test (conducted 2 weeks later). For children who heard passive primes (18), the comparable figures were 4.9/8 (0.61), 5.2/8 (0.65), and 9.6/16 (0.60). Children in the control condition (17) were numerically lower on their comprehension scores 4/8 (0.50) but not significantly different from experimental children. There was no shift in the number of children who were above chance before and after priming, whether the priming was active or passive.

Computation of children's individual comprehension scores allows a comparison, for each child, between comprehension and priming.

Relationship between comprehension and priming

We examined the relation between children's passive comprehension scores at baseline and their success in producing passive descriptions according to strict criteria. Table 6 displays the contingencies between being above chance or not on the baseline comprehension (7/8 or 8/8 for each child) and producing at least one passive or not during priming. The contingencies were separately computed for the passive and active priming conditions.

For children in the passive priming condition there was a positive relation between production of strict passives and baseline comprehension (*Fisher's Exact Test*, $p < .02$), indicating that children who were successfully primed were also more likely to understand passives (4/6 children who produced passives understood them; 4/5 children who understood passives produced them). There was no relation for children in the active priming condition (0/2 children who produced passives understood them; 0/3 children who understood passives produced them). Across both groups, 4/8 children who produced passives understood them. Fig. 3 graphically

Table 6
Contingencies between comprehension and production: number of children who did and did not produce passives in priming as a function of whether they were or were not above chance in comprehension before priming, and whether they received active or passive priming

Priming condition	Comprehension			
	Above chance		Not above chance	
	Produced passives			
	Yes	No	Yes	No
Active	0	3	2	13
Passive	4	1	2	11

Table 5
Repetition results: number (and percentage) of included constituents in children's *non-verbatim* repetitions of active and passive sentences

Priming condition	Constituent					
	NP1	Auxiliary	Verb stem	Inflection	*by*	NP2
Active	19 (46)	5 (15)	33 (80)	30 (91)	n/a	34 (82)
Passive	77 (93)	15 (31)	49 (60)	22 (45)	65 (79)	79 (96)

Note: Denominators for the computation of NP1 and NP2 inclusion rates are the total number of non-verbatim repetitions (41 for the active condition, 82 for the passive condition). Denominators for auxiliary and inflection inclusion rates are the total number of non-verbatim repetitions that contain a verb stem (33 for the active and 49 for the passive).

displays the relation between comprehension and production. As can be seen, comprehension of passives, considered independently of priming condition, is neither a necessary nor sufficient condition to produce strict passives. It is possible that comprehension bolstered by priming leads to production of passives, but our numbers are too small to consider this further.

Discussion

Our study of syntactic priming in children aged 35–42 months shows that abstract syntactic priming is successful with young 3-year-olds, supporting Early Abstraction views of language acquisition. Children who were primed with passives were significantly more likely to produce full passive sentences than were children primed with actives. Children who did not receive any priming produced no passives at all. The priming here was genuinely abstract rather than lexical: our experiment used full lexical noun phrases as arguments, presented a given verb only once, had strict criteria for what counted as a passive, and provided minimal input—only 8 primes. Contrary to suggestions that priming may be tied to the re-use of pronominal arguments (Savage et al., 2003), only a small proportion of strict transitive descriptions (active or passive) contained pronouns, and no passive sentences did.

The effective component of the priming was having the children hear and repeat the priming sentence before describing a new picture. The comprehension task by itself did not promote priming (Shimpi et al., 2007). That is evident from two facts. First, there was zero priming for the control children, who heard the comprehension sentences but did not receive priming sentences. Second, above-chance comprehension alone did not result in production of passives. Of the children who were significantly above chance in comprehension before priming, only the ones who received passive priming produced full passives; conversely, of those who produced passives, only half were above chance on comprehension.

Our method of reducing cognitive demands by reviewing the lexical items with the children before priming allowed the children to demonstrate their abstract representations. Previous work has failed to demonstrate abstract priming of full passives in children younger than age 4, except with intensive input (de Villiers, 1984) or training (Brooks & Tomasello, 1999). Our methods were designed to reduce or eliminate processing burdens extrinsic to the production of passives but without providing intensive input or training. The children's success suggests that prior failures to demonstrate abstract priming in young children were due to task demands and children's limited skills as speaker-listeners, rather than to their lack of knowledge. Supporting that interpretation is the success of 3-year-olds in producing a combination of full and truncated passives when task demands are reduced (Shimpi et al., 2007).

To facilitate comparisons with other findings, we used several coding schemes. Our lax coding scheme included incorrect repetitions and non-transitive descriptions (e.g., Huttenlocher et al., 2004; Shimpi et al., 2007). Another coding scheme used adult criteria, so that only trials that occurred after children had correctly repeated the prime were included. With that scheme, the priming effect was numerically much larger in 3-year-olds than in adults. This result is in line with findings showing that less skilled speakers generally show larger priming effects than highly proficient speakers: adult aphasics (Hartsuiker & Kolk, 1998); children with SLI (Leonard et al., 2000); children who stutter (Anderson & Conture, 2004); second language learners (Flett, 2006). Priming may be larger in young children because their smaller linguistic repertoire produces less competition among structures to convey meaning (Hartsuiker & Kolk, 1998; Pickering & Branigan, 1999), because priming is stronger earlier in learning (Chang et al., 2006), because priming is stronger for less frequent structures and passives are less frequent in children's repertoire than adults' (V.S. Ferreira, 2003), or because the pragmatic felicity conditions are not well understood by beginning learners (Flett, 2006). The important point is that enhanced priming occurs in the youngest age group to date to exhibit abstract priming of full passives, as would be predicted from other studies with non-proficient speakers.

Although our young 3-year-olds demonstrated priming on a par with older children and adults, other aspects of their performance—particularly their repetition of the priming sentences and their comprehension of the passive—deviated from adult behavior. Given the children's success with priming, we analyze those differences as primarily due to 3-year-olds' cognitive limitations and their incomplete mastery of the language-specific morphosyntactic details of an infrequent structure like the passive, rather than as a reflection of lack of abstract representations. Adults perform close to ceiling in repeating priming sentences (e.g., Bock & Griffin, 2000), but our children omitted various sentence constituents and grammatical morphemes in repeating actives as well as passives. Children made repetition errors in 0.29 of actives and in 0.58 of passives. Thus, even actives are taxing enough for children to make repetition errors. In 2-year-olds' repetition of actives, children include more constituents when they have two opportunities to hear and repeat the sentences, suggesting that performance constraints are at work (Valian & Aubry, 2005). The contrast between our children's ability to exhibit abstract priming on the one hand, and their imperfect repetition on the other, supports claims that non-adult performance need not entail non-adult competence (Fisher, 2002; Valian & Aubry, 2005).

Children's comprehension scores on fully reversible passives with animate characters were above chance at every measuring point, indicating that on average our 3-year-olds understood passives. The children, who ranged in age from 2;11 to 3;6, appear to have been aided in the comprehension task by our lexical review: they performed comparably to older 3-year-olds in previous experiments (e.g., the youngest group in Gordon & Chafetz, 1991—age range 3;0–4;2, mean age 3;6). Analyses by age showed no age effects: the children aged 2;11–3;1 performed as well as the children aged 3;4–3;6. The comprehension data thus support the priming data: both suggest that young 3-year-olds' grammars represent the passive abstractly.

With comprehension, however, performance was far from perfect. The comprehension task is difficult. The child must analyze two flanking pictures, remember the test sentence, and decide which picture fits it better. Adults also find passives difficult. They are slower to confirm passive sentences than actives (Brookshire & Nicholas, 1980; Slobin, 1966) and less accurate in assigning semantic roles to passives (F. Ferreira, 2003). We propose that children understand that the relation between surface noun phrases and semantic roles is flexible, but that, to a greater degree than with adults, their understanding does not guarantee excellent performance.

Previous research on children's early sentence representations has examined either comprehension or production, usually reaching opposing conclusions with respect to the question of abstraction. Comprehension researchers have typically emphasized the abstract nature of children's knowledge (Fisher, 2002), whereas production researchers have stressed its item-specificity (Tomasello, 2000b). By simultaneously examining comprehension and production of the same syntactic structure, we are able to provide converging evidence of children's abstract knowledge. Taken together, our production and comprehension results support Early Abstraction accounts. Three-year-olds can access two-level representations in which the concepts "agent" and "patient" exist separately from the grammatical relations "subject" and "object". The children also flexibly map the connections between those two-levels.

Syntactic priming and learning

There are several accounts of the mechanism underlying priming. On a spreading activation model of sentence production (Dell, 1986), hearing a structure activates a syntactic representation in the speaker's grammar (Bencini, 2002; Branigan, 2007; Branigan et al., 1995; Hartsuiker & Kolk, 1998; Pickering & Branigan, 1998). On a procedural learning account, priming strengthens a procedure linking a syntactic representation with its use (Bock & Griffin, 2000). Both models assume that an existing syntactic representation is activated. They differ in whether activation is transient or longer-lasting and differ in the kind of network that is proposed. On a dual-path model using a connectionist network, priming promotes the development of syntactic representations as well as procedural learning through error-based learning (Chang et al., 2006).

Our children showed some evidence of learning: when scored via the lax coding scheme, that allows truncated passives, there were more passives produced in the second than the first half of trials. The syntactic priming paradigm might be particularly conducive to children's learning of the primed structure because it provides the child with STRUCTURED INPUT, which has been found to result in learning and generalization in 2-year-olds (Valian & Casey, 2003). From a review of successful syntax interventions with young children, Valian and Casey propose that structured input works if: (1) the child is required to parse each input sentence, by actively engaging the structure via imitation or act-out tasks, (2) input is concentrated on one structure over a short period of time; (3) a number of different exemplars of the construction are given; (4) the child attends to the form of the sentence more than to its meaning. It is yet unknown whether each one of the properties of structured input is necessary and how this may interact with the type of learning task (e.g., repetition, as in Valian and Casey, or spontaneous production of target structures, as in syntactic priming experiments). One finding that suggests the importance of property 3—multiple exemplars—is reported in a study by Savage, Lieven, Theakston, and Tomasello (2006). Savage et al. found greater long-term priming of passive sentences in 4- to 6 year-olds when the primes contained different verbs rather than the same verb. One limitation of that study, however, is that it did not investigate priming of the more abstract type, i.e., priming in the absence of lexical overlap in the nouns as well as the verbs. In addition, the children were, relatively speaking, "old" language learners.

The existence of abstract priming of passives in young children who in other respects do not have full command of the use of this structure, as evidenced by production of passive-like utterances, suggests that priming is not solely activation of a pre-existing linguistic representation but also reflects implicit learning of the passive (Chang et al., 2006). If passive-like (but either incomplete or ungrammatical) descriptions are seen as attempts to produce structures similar to the ones experienced in the primes, these findings suggest that children's attempts to produce passive descriptions build up over time.

From a developmental perspective, the priming-as-learning view raises the question of whether priming is learning production-specific procedures (Bock &

Griffin, 2000) or whether priming may be more generally construed as learning language (Bencini, 2002; Bock et al., 2007). If comprehension and production share linguistic representations (Bencini, 2002; Branigan et al., 1995; Bresnan & Kaplan, 1984; Chang et al., 2006; Pickering & Garrod, 2004), changes in one modality should transfer to the other modality. If this hypothesis is correct, we should have seen improvement in children's comprehension of reversible passives as a result of receiving passive priming in the production task (production-to-comprehension priming) or, alternatively, having performed an earlier comprehension task during baseline testing (comprehension-to-comprehension priming). We did not find evidence for improved comprehension after priming.

We thus have two somewhat inconsistent results: more attempts to produce a passive during priming but lack of improvement in comprehension. It is possible that with more sensitive measures of comprehension, such as looking times, more subtle changes in children's comprehension could be detected. Using looking time measures, comprehension-to-comprehension priming has recently been found with dative structures in 3- and 4-year-olds (Thothathiri & Snedeker, 2008). Although that study found that the structure of the priming sentence influenced subsequent eye-movements to a target picture, it did not examine improvement of comprehension over time. Another possibility is that the same processes that make production-to-comprehension priming difficult to observe in adults also operate in children. Finally, the fact that the agents and patients in the comprehension trials were animate, whereas those in the priming trials were inanimate, may have been a factor (Bock et al., 1992). For the time being, the question of whether priming in production leads to improvement in comprehension is still open.

Conclusion

The results support our claims that 3-year-olds: (a) represent syntactic notions of "subject" and "object"; (b) separately represent semantic notions of "agent" and "patient"; (c) represent the category verb; (d) have abstract sentence-level representations; (e) can map flexibly between semantic and syntactic levels. In short, our results suggest that Early Abstraction accounts of language acquisition are correct at least as early as age 3.

Acknowledgments

This research was supported by an NIH-NRSA post-doctoral fellowship (G.B.) and by NSF award SBE-0123609 to Hunter College (V.V.V.). Portions of this work were presented at the 3rd Annual Workshop in Language Production, Chicago, IL; the 12th Annual Conference on Architectures and Mechanisms for Language Processing, Nijmegen, The Netherlands; the 31st Annual Boston University Conference on Language Development, Boston, MA; and the 47th Annual Meeting of the Psychonomic Society, Houston, TX.

We thank Danielle Cherrick, Tamara Spiewak, Lucy Buchholz, Emily Carlin, Amy Geojo, and Christina Theodorou for their fine work. We thank Martin Chodorow, Mary C. Potter, Adele Goldberg, and Annemarie Nicols-Grinenko for helpful comments. We are indebted to our anonymous reviewers for their insights and suggestions. Thanks to the children and parents who so generously contributed their time.

Appendix

Priming sentences (1–8)

1. The presents are carried by the wagon/The wagon is carrying the presents.
2. The truck is followed by the police car/The police car is following the truck.
3. The pasta is cooked by the stove/The stove is cooking the pasta.
4. The milk is stirred by the spoon/The spoon is stirring the milk.
5. The chair is covered by the blanket/The blanket is covering the chair.
6. The ball is bounced by the racket/The racket is bouncing the ball.
7. The stripe is painted by the brush/The brush is painting the stripe.
8. The glass is filled by the water/The water is filling the glass.

Target pictures (1–8)

1. Truck dumping dirt.
2. Crayon coloring book.
3. Knife slicing lemon.
4. Cloud watering flower.
5. Truck lifting car.
6. Sun melting icecream.
7. Knife peeling apple.
8. Hammer cracking egg.

References

Anderson, J. D., & Conture, E. G. (2004). Sentence-structure priming in young children who do and do not stutter. *Journal of Speech, Language and Hearing, 47*, 552–571.

Aston, G., & Burnard, L. (1998). *The BNC handbook: Exploring the British National Corpus with SARA*. Edinburgh: Edinburgh University Press.

Bencini, G. M. L. (2002). The representation and processing of argument structure constructions. University of Illinois: Unpublished Ph.D. dissertation.

Bencini, G. M. L., & Goldberg, A. E. (2000). The contribution of argument structure constructions to sentence meaning. *Journal of Memory and Language, 43*, 640–651.

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

Bock, J. K. (1995). Sentence production: From mind to mouth. In J. L. Miller & P. D. Eimas (Eds.). *Handbook of perception and cognition: Speech, language and communication* (Vol. 11, pp. 181–216). Orlando, FL: Academic Press.

Bock, J. K., Dell, G., Chang, F., & Onishi, K. (2007). Persistent structural priming from language comprehension to language production. *Cognition, 104*, 437–458.

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

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

Bock, J. K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review, 99*, 50–171.

Borer, H., & Wexler, K. (1987). The maturation of grammar. In T. Roeper & E. Williams (Eds.), *Parameter setting* (pp. 123–172). Dordrecht: Reidel.

Borer, H., & Wexler, K. (1992). Bi-unique relations and the maturations of grammatical principles. *Natural Language and Linguistic Theory, 10*, 147–189.

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

Branigan, H. P., Pickering, M. J., Liversedge, S. P., Stewart, A. J., & Urbach, T. P. (1995). Syntactic priming: Investigating the mental representation of language. *Journal of Psycholinguistic Research, 24*, 489–506.

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

Bresnan, J., & Kaplan, R. M. (1984). Grammars as mental representations of language. In W. Kintsch, J. R. Miller, & P. G. Polson (Eds.), *Method and tactics in cognitive science* (pp. 103–135). Hillsdale, NJ: Erlbaum.

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

Brookshire, R. H., & Nicholas, L. E. (1980). Verification of active and passive sentences by aphasic and nonaphasic subjects. *Journal of Speech and Hearing Research, 23*, 878–893.

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

Casenhiser, D., & Goldberg, A. E. (2005). Fast mapping between a phrasal form and meaning. *Developmental Science, 8*, 500–508.

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

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

Childers, J., & Tomasello, M. (2001). The role of pronouns in children's acquisition of the English transitive construction. *Developmental Psychology, 37*, 739–749.

Clark, H. H., & Malt, B. C. (1984). Psychological constraints on language: A commentary on Bresnan and Kaplan and on Givón. In W. Kintsch, J. R. Miller, & P. G. Polson (Eds.), *Method and tactics in cognitive science* (pp. 191–214). Hillsdale, NJ: Erlbaum.

Dell, G. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review, 93*, 283–321.

Demuth, K. (1989). Maturation and the acquisition of the Sesotho passive. *Language, 65*, 56–80.

de Villiers, J. G. (1984). *Learning the passive from models: Some contradictory data*. Paper presented at the Boston University Conference on Language Development, Boston.

Fernandes, K., Marcus, G., DiNubila, J., & Vouloumanos, A. (2006). From semantics to syntax and back again. *Cognition, 100*, B10–B20.

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

Ferreira, V. S. (2003). The persistence of optional complementizer production: Why saying "that" is not saying "that" at all. *Journal of Memory and Language, 48*, 379–398.

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

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

Flett, S. (2006). A comparison of syntactic representation and processing in first and second language production. Edinburgh University: Unpublished Ph.D. dissertation.

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

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

Goldberg, A. E., & Bencini, G. M. L. (2005). Support from processing for a constructional approach to grammar. In A. Tyler, M. Takada, Y. Kim, & D. Marinova (Eds.), *Language in use: Cognitive and discourse perspectives on language and language learning* (pp. 3–18). Washington, DC: Georgetown University Press.

Gordon, P., & Chafetz, J. (1991). Verb-based vs. class-based accounts of actionality effects in children's comprehension of the passive. *Cognition, 36*, 227–254.

Hartsuiker, R. J., & Kolk, H. H. J. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language, 62*, 221–254.

Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology, 45*, 337–374.

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

Kemp, N., Lieven, E., & Tomasello, M. (2005). Young children's knowledge of the "adjective" and "determiner" categories. *Journal of Speech Language and Hearing Research, 48*, 592–609.

Leonard, L., Miller, C., Grela, B., Holland, A., Gerber, E., & Petucci, M. (2000). Production operations contribute to the grammatical morpheme limitations of children with specific language impairment. *Journal of Memory and Language, 43*, 362–378.

Lieven, E., Pine, J. M., & Baldwin, G. (1997). Lexically-based learning and early grammatical development. *Journal of Child Language, 24*, 187–219.

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

Masson, G. R., & Loftus, M. E. J. (2003). Using confidence intervals for graphically based data interpretation. *Canadian Journal of Experimental Psychology, 57*, 203–220.

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

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language, 17*, 357–374.

Naigles, L., Bavin, E., & Smith, M. (2005). Toddlers recognize verbs in novel situations and sentences. *Developmental Science, 8*, 424–431.

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

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

Pickering, M. J., & Branigan, H. P. (1999). Syntactic priming in language production. *Trends in Cognitive Science, 3*, 136–141.

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences, 27*, 169–225.

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

Savage, C., Lieven, H., Theakston, A., & Tomasello, M. (2006). Structural priming as implicit learning in language acquisition: The persistence of lexical and structural priming in 4-year-olds. *Language Learning and Development, 2*, 27–49.

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

Slobin, D. (1966). Grammatical transformations and sentence comprehension in children and adults. *Journal of Verbal Learning and Verbal Behavior, 5*, 219–227.

Stromswold, K., Eisenband, J., Norland, E., & Ratzan, J. (2002). *Tracking the acquisition and processing of English passives: Using acoustic cues to disambiguate actives and passives*. Paper presented at the annual meeting of the CUNY sentence processing conference, New York, NY.

Studebaker, G. A. (1985). A "rationalized" arcsine transform. *Journal of Speech and Hearing Research, 28*, 455–462.

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

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

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

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

Tomasello, M., & Stahl, D. (2004). Sampling children's spontaneous speech: How much is enough? *Journal of Child Language, 31*, 101–121.

Valian, V. V. (1986). Syntactic categories in the speech of young children. *Developmental Psychology, 22*, 562–579.

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

Valian, V. V., & Aubry, S. (2005). When opportunity knocks twice: Two-year-olds' repetition of sentence subjects. *Journal of Child Language, 32*, 617–641.

Valian, V. V., & Casey, S. (2003). Young children's acquisition of *wh*-questions: The role of structured input. *Journal of Child Language, 30*, 117–143.

Valian, V. V., Solt, S., & Stewart J. (2008). Abstract categories or limited-scope formulae? The case of children's determiners. Unpublished manuscript, Hunter College—CUNY.

Xiao, R., McEnery, T., & Qian, Y. (2006). Passive constructions in English and Chinese. A corpus based contrastive study. *Language in Contrast, 6*, 109–149.