

Structural Priming as Implicit Learning in Language Acquisition: The Persistence of Lexical and Structural Priming in 4-Year-Olds

Ceri Savage
University College London

Elena Lieven
*Department of Psychology
Manchester University
Max Planck Institute for Evolutionary Anthropology
Leipzig, Germany*

Anna Theakston
*Department of Psychology
Manchester University*

Michael Tomasello
*Department of Psychology
Manchester University
Max Planck Institute for Evolutionary Anthropology
Leipzig, Germany*

Savage et al. (2003) found that 4-year-old children are subject to sentence-level structural priming in conditions of high lexical overlap between prime and target. The present study investigated whether the process of priming also leads to significant implicit learning. Forty-four English-speaking 4-year-old children were asked to describe a prime picture by repeating a passive sentence, and then they were left to their own devices to describe a target picture. Some children were exposed to a prime

set consisting of identical passive sentences across items, whereas others received varied passive sentences (using different verbs) across items. There were 2 main findings. First, varied primes were significantly more effective than identical primes in eliciting passive sentences from the children, showing both a greater immediate effect and a longer lasting effect (varied primes, but not identical primes, were still effective after a week). Second, the effect of the varied primes persisted for up to a month, but only for those children who received the opportunity to name pictures at the 1-week interval (reinforcement). These results provide the first evidence that priming in young children is sensitive to variation across the prime set and that it can be quite long lasting, suggesting that during the priming session children are also learning and so modifying their linguistic representations.

Priming is a tool that has been widely used in psychological research to explore the nature of underlying cognitive and linguistic representations. The basic idea is that a preceding stimulus, for instance, a particular word or sentence, increases the likelihood that the hearer will produce a related (or identical) word or sentence. The relation between the preceding stimulus (the prime) and the hearer's response allows for inferences about the nature of the hearer's cognitive or linguistic representations. Specifically, if a priming effect occurs, we infer that the participant possesses a cognitive representation of the structure in question. By manipulating the relationship between prime and target we can assess the nature of these representations.

Priming experiments with adults have explored a great variety of cognitive representations and the connections between them, including in the case of language the semantic networks and syntactic structure (see Wagner & Koutstaal, 2002, for a review). Recent work suggests that, for adults, priming can even occur for abstract linguistic structures independently of particular words or morphemes, thus indicating an abstract representation of the construction in question, so called structural priming (Bock & Griffin, 2000). For example, Pickering and Branigan (1998) found that the effect of priming the dative construction (e.g., *X gave Y a Z*) is unaffected by changes in lexical items (including verbs) and their morphology across prime and target responses. This indicates that the adults' representation of dative construction is verb-general and abstracts across specific detailed structures such as tense, aspect, or number.

Recently there have been suggestions in the adult literature that priming should be seen as a form of implicit learning. Traditionally, priming has been considered to reflect the transient activation of already-existing static knowledge (e.g., Clark & Loebell, 1990; Pickering & Branigan, 1999). Thus it was seen as a means of indirectly accessing existing knowledge, rather than being a changing force on knowledge or means of acquisition. If linguistic knowledge is fixed, this makes sense. However, evidence is accumulating to suggest that grammatical knowledge is dynamic and continually influenced by experience (e.g., Bybee, 1998; Croft,

2001), existing as a form of procedural knowledge (e.g., Bock & Griffin, 2000; Bybee, 1998; Chang, Dell, Bock, & Griffin, 2000; Luka, 1999). If this is the case, perhaps what was thought of as priming could also act as linguistic experience contributing to learning, changing (strengthening, expanding) linguistic representations as a result.

Evidence for this proposal comes from a number of recent findings suggesting that the effects of priming in adults may be relatively long lasting and, therefore, cannot be accounted for simply by transient short-term memory effects (e.g., Bock & Griffin, 2000; Chang et al., 2000; Hartsuiker & Kolk, 1998; Hartsuiker, Kolk, & Huiskamp, 1999; Luka, 1999). The authors suggest that priming may stem from an experience-dependent adjustment within the utterance-building system. However, even if this is correct, the effect for adults is, presumably, not very great in terms of the already entrenched and abstract nature of their linguistic representations and will probably not make a great deal of difference to how they perform in everyday life or in subsequent experimental tests—unless, perhaps, they recall the exact conditions of the priming experiment that they have undertaken. For instance, over their life span adults hear enormous numbers of passive sentences, and so over time the underlying representations of this construction develop stability. We could expect that new input will not immediately alter these representations to any large extent, and probably for any single instance, the influence will rapidly subside if it is not subsequently repeated and strengthened.

Children thus represent an extremely interesting case because their linguistic representations are built on a much smaller number of exemplars than those of adults—which might account for the fact that they become abstract and productive only very slowly. For example, overgeneralizations in children's spontaneous speech (e.g., "Don't giggle me" in which an intransitive verb is used in a transitive construction) virtually never occur before 2½ years of age and mostly occur after 3 years of age (Pinker, 1989, using Bowerman's 1982, 1988 data). Experimentally, when children below 3 years of age are taught a novel verb in one construction (e.g., a passive), they find it very difficult to use that verb in a different construction (e.g., an active transitive)—whereas older children do this with ease (see Tomasello, 2000, for a review). These findings suggest that, unlike adults, young children's linguistic constructions are not abstract in the sense that they are independent of the particular words and morphemes involved, but rather particular linguistic content is almost always a part of the representation of the construction—at least if their productions are taken as the primary evidence (Tomasello, 2003).

In another experimental paradigm using production, Akhtar (1999) found that if young children heard a well-known verb used in a "weird word order" (e.g., "Ernie Bert pushing"), when it was their turn with new characters, they almost always corrected this order (e.g., "Mickey's pushing Minnie"). However, with novel verbs, they did not correct in this way consistently until they were 4 years of age (see Abbott-Smith, Lieven, & Tomasello, 2001, for confirmation of this result). More re-

cently, Matthews, Lieven, Theakston, and Tomasello (2005) performed a similar experiment with only real English verbs and found that children's corrections could be predicted quite well on the basis of the frequency of those verbs in children's linguistic experience: Verbs they knew well they corrected, whereas verbs they had heard less often they did not. Studies in this experimental paradigm demonstrate especially clearly that young children's linguistic representations of syntactic constructions contain specific words, especially verbs, and are not totally abstract like adults'. This conclusion accords with a number of recent proposals suggesting that, if cognitive representations retain information about the variety of individual instances, they may be felicitously described as being either weaker or stronger based mainly on the type and token frequency of the constitutive exemplars (e.g., Bybee, 2003; Munakata, McClelland, Johnson, & Siegler, 1997).

One potential limitation of the studies with young children is that they all focus on children producing some kind of utterance that they have not heard in the immediate context, and indeed they require children to use words in ways other than what they have just heard—which might be thought of as a kind of negative priming. Recently, therefore, two different laboratories have adapted the adult structural priming technique for use with children. The question in these studies was the nature of children's representations' underlying syntactic constructions. First, in a study with 3-, 4-, and 6-year-old children, Savage, Lieven, Theakston, and Tomasello (2003), primed children with either an active or a passive sentence and then invited them to describe a new picture (with new characters and actions) that could be described with either *active* or *passive*. The younger children showed a priming effect only when there was high lexical overlap between the prime and target, that is, when the adult used pronouns in his or her prime that the child could then use in his or her response (A: It pushed it, C: It cut it). In contrast, the 6-year-olds showed a priming effect in both the high overlap condition and the more abstract, low overlap condition in which the adult used nouns in the prime, and the child had to use different nouns for the new picture (A: The digger pushed the bricks, C: The knife cut the cake).

Huttenlocher, Vasilyeva, and Shimpi (2004) used a design that was very similar to that of Savage et al. (2003). They found a structural priming effect (i.e., independent of lexical content) for both transitives and datives with children aged between 4;5 and 5;8. Because Savage et al.'s 4-year-olds ranged from 3;10 to 4;6 and had a mean age that was a full 6 months younger than the 4-year-olds in the Huttenlocher et al. study (4;2 vs. 4;8), the two studies together present a picture of gradual transition from lack of abstract representations at 3 years, through partially abstract representations at 4 years, to even more abstract representations by the time children are 5 years old and older. This is a slightly older age than that found with the seemingly more demanding production methodologies reviewed above.

Both of these priming studies also provided some evidence relevant to the proposal from the adult literature that experience in the priming session constitutes ex-

perience relevant for learning. Thus, Savage et al. (2003) found that the number of passives that children produced built up across the five trials. More surprisingly, the order effects in their data suggested that exposure to primes during the first session had an effect on the targets produced during the second session between 1 and 3 weeks later. Specifically, the effect of exposure to active primes in Session 1 seemed to persist over time and suppress the number of passives produced in Session 2. Huttenlocher et al. (2004; Study 3) examined more directly the retention of syntactic form over time for children who had been primed, albeit over a relatively short time period. They found that the priming effect for children sometimes lasted over an entire set of 10 intervening trials, concluding that the persistence of the priming effect across at least 10 trials was due to learning.

This study builds on these findings by exploring timing and frequency factors that affect the maintenance of priming over time in young children. We first investigated the persistence of the priming effect by presenting targets immediately after primes, a week after the primes were given, and a month after the primes were given. If priming reflects a form of learning in children, it could be expected that the effect would persist across a lag of 1 week, or possibly across a month. Second, we also manipulated the child's experience by varying the frequency with which the target constructions were elicited. That is, in some cases we gave children a chance to display an effect of the original priming more than once across the month-long time period, in which case we might expect a kind of self priming at the 1-month elicitation for those children who produced something at the intermediate point. Third, we also manipulated the ratio of type and token frequencies in the prime stimulus; that is, in one condition, the prime sentence was always exactly the same, whereas in the other we provided systematic variation by using different verbs in the same construction frame. Although other interpretations are possible (e.g., more different verb types increases activation to, but does not change, an existing schema), an effect of type frequency would also be consistent with models stressing that type frequency leads to abstraction (e.g., Bybee, 1995; Childers & Tomasello, 2001). Moreover, if each priming trial contributes to a change in the child's representation of the construction, as in the learning interpretation, then type variation within the construction used in priming might be expected to lead to greater child priming or learning effects over trials.

METHOD

Participants

Sixty-six monolingual English-speaking children, recruited from two schools in the Wirral area, United Kingdom, participated. Forty-four children participated in the experimental groups, and 22 children formed a control group. In the combined

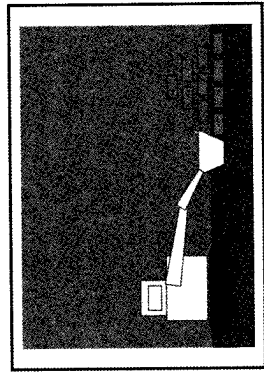
experimental groups, the children ranged in age from 4;5 to 5;6 ($M = 4;11$), with 29 boys and 15 girls. All complied with the procedure. Eight more children who began participation in these groups were excluded because they were unavailable for Session 3. In the control group, the children ranged in age from 4;0 to 5;2 ($M = 4;8$), with 7 boys and 15 girls. All complied with the procedure. Ten more children who began participation in the control group were excluded because they were unavailable for Sessions 2 or 3, or both.

Materials and Design

Cartoon action scenes were created and presented in Microsoft PowerPoint 2000 on a Toshiba laptop computer. Three intransitive action-event cartoons were created for the warm-up, depicting an animal performing a self-perpetuated action (a bird flying, a cow running, and a lion roaring). For the experiment, 20 action-event cartoons were created depicting two inanimate objects performing transitive actions, each lasting between 3 and 13 sec (M display time = 9.85 sec; see Figure 1 for examples). The "actors" were the inanimate objects; for example, a crayon was shown coloring in and a knife was shown cutting a cake. Inanimates were used because animacy has been found to interact with people's preference for actives or passives. See Bock, Loebell, and Morey (1992) for adults and Lempert (1990) for preschool children. Piloting of the stimuli with adults and 3-year-olds established that the actions and characters or objects were recognizable and could be described with either active or passive sentences.

There were five test items, each comprising a prime cartoon (with a spoken description; see below) and its associated target cartoon. The five transitive verbs-actions used in primes were *catch*, *dry*, *push*, *shoot*, and *wrap*. The five transitive verbs-actions depicted in target pictures were *break*, *close*, *color*, *cut*, and *lock*.

1. Prime stimulus (*push*)



2. Target stimulus (*break*)

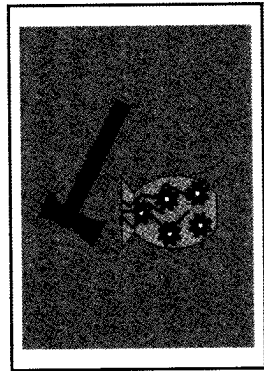


FIGURE 1 Examples of cartoon stimuli.

Three target sets were created, which all depicted the same verbs-actions but with different objects. Although it would have been desirable to vary the verb across the target sets, this was not possible because there are fewer than 15 verbs used spontaneously in the passive by 4-year-olds that can also be acted out by inanimate objects. This is important because if it turned out that the children did not yet use the chosen verbs in the passive, then any priming effect would be lost for the trials in which these verbs were used. The verbs used were thus those that appeared in passive sentences in the spontaneous speech of 3-year-olds in a study by Israel, Johnson, and Brooks (2000). Those used as primes all appeared in the eventive passive in naturalistic speech, and those used as targets all appeared as alternations in naturalistic speech; that is, they were used with the same sense both as a passive participle and in an active construction within a reasonably short period.

Despite using the same verbs-actions across the three target sets, the target pictures in each were not identical. Different objects were used to depict the same verbs-actions in each set. This allows increased confidence to interpret any priming effect as being a linguistic effect caused by the particular syntactic construction of the prime sentence, rather than as being a result of context-based memory for a specific picture.

In total there were five primes and 15 targets; five primes and five targets for the first session, five targets for the second session and five targets for the third session. Stimuli were presented in random order across sessions and selected randomly for those groups who did not receive a second session. Each session lasted around 5 to 10 min.

The study employed a mixed design (see Figure 2). For the experimental groups, all of the children received prime sentences of the type termed *high overlap* in Savage et al. (2003); for example, "It got pushed by it" or "It got shot by it." Stimulus type was manipulated between subjects, so that half of the children re-

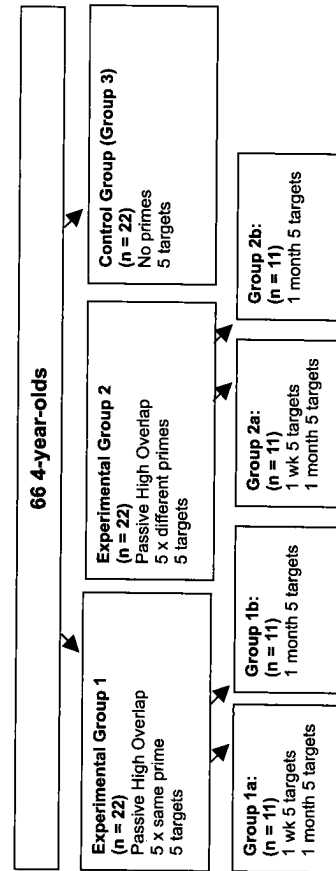


FIGURE 2 Design for experimental groups.

ceived five identical primes (Groups 1a and 1b; Figure 2), and half of the children received five different primes (Groups 2a and 2b; Figure 2). For each child in Groups 2a and 2b, a different pair of objects appeared in each different prime item. For each child in Groups 1a and 1b, a single prime item was selected randomly from the set of five different primes used for Groups 2a and 2b. The verb-action that was depicted by the primes therefore varied across children, although the objects that acted out the verb-action remained the same across each presentation of that prime for a single child.

Priming reinforcement was also manipulated between subjects, so that half of the children produced targets immediately after receiving the primes, after 1 week and after 1 month (Groups 1a and 2a; Figure 2), and half produced targets immediately after receiving the primes and after 1 month, with none after a week (Groups 1b and 2b; Figure 2). Time lag (immediate targets, targets after 1 week, and targets after 1 month) was manipulated within groups, with the same children producing targets immediately and after the appropriate lags (depending on whether priming reinforcement occurred or not). The three lags will be referred to as Time 1 (T1), Time 2 (T2), and Time 3 (T3), respectively. For the control group, 22 children were tested at all three sessions using the same procedure as the experimental groups except that they received no primes at Session 1, so their target responses were all spontaneous, nonprimed utterances. This provided a baseline by which to measure priming in the experimental groups.

Procedure

For Session 1 the procedure replicated that of Savage et al. (2003). Each child began by taking part in a warm-up session in which he or she talked to the experimenter about what the cartoon animals were called that were used to model intransitive actions and practiced producing and repeating sentences describing them. Then the child was presented with the five items of his or her first block. For each item the experimenter first showed the picture for the prime and described it with its appropriate sentence four times; the child was then told to repeat it. If the child did not comply by repeating the prime sentence, he or she was encouraged to do so by first repeating the sentence word by word and then fully on his or her own. If children still did not produce the full sentence uninterrupted, they were shown the target anyway and the procedure progressed without alteration. Then the target picture was presented and the experimenter asked the child "What's happening?" "What happens?" or "What happened?"

In the later sessions (at 1 week and 1 month), five targets were presented with no primes preceding them, and the same elicitation questions were used. During the experimental sessions, the experimenter kept an online written record of child performance, and sessions were recorded on minidisks as well (a small number of minidisk sessions were lost through equipment failure or experimenter error).

The control group received the same target pictures as the experimental groups but with no primes. These children produced spontaneous target descriptions at the first session, again with different target pictures after a week and with different target pictures after a month.

Scoring

Scoring was done as follows. First, a child was given credit for repeating the prime sentence if no more than minor parts of the sentence were missing or changed (e.g., missing determiner or past-tense inflection) and if the prime construction type remained identifiable. For example, the response, "Bricks got push by the digger" would be accepted as an adequate repetition of "The bricks got pushed by the digger" because the syntax was preserved as unambiguously passive, whereas "push bricks" would be rejected as syntactically ambiguous. All children repeated all primes. Response utterances were classified as passive (including truncated passives such as "he got shot"), active (transitives), or other. Again, morphological features, such as missing determiners, were allowed, but the sentence had to be syntactically unambiguous. Actives were scored only if they contained a direct object after the verb, but omission of the participant was allowed; for example, "broke the vase" but not "the hammer broke" would be scored as active. Adjectival passives were excluded on the grounds that their status as true passives is equivocal (Israel et al., 2000). Only the first sentence-like utterance (i.e., excluding single-word naming of characters) produced after exposure to each prime sentence was included in the analysis, with any subsequent utterances being disregarded (not so frequent). For example, if a child produced the following response, only the passive response would be scored because it preceded the active utterance, and vice versa for the reverse sequence: "Hammer [pause 5 sec] The vase got broken by the hammer [pause 5 sec] The hammer broke it."

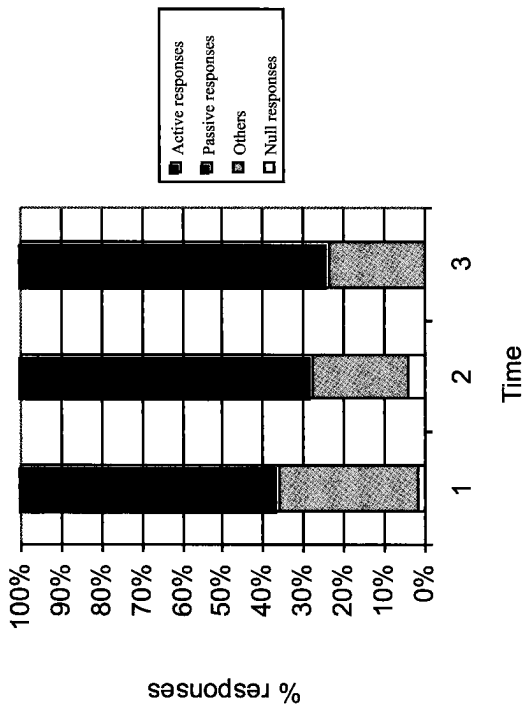
RESULTS

The Baseline

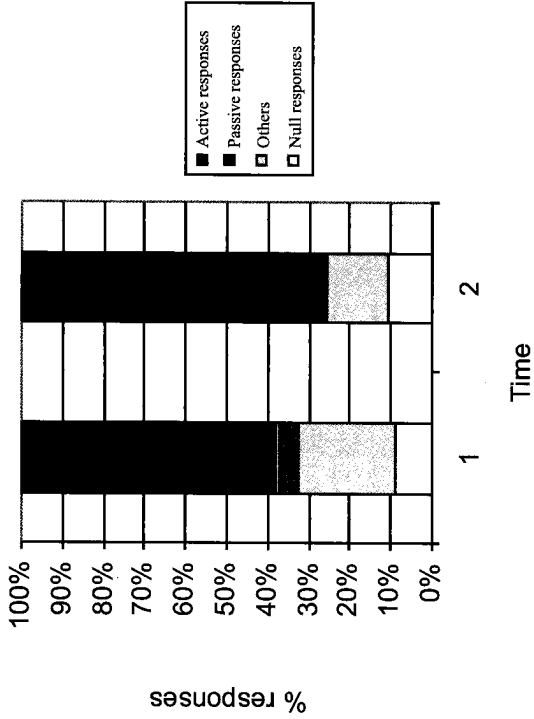
Before the hypotheses set out in the introduction could be tested, it was important to ensure the response of the control children constituted an appropriate baseline. The breakdown of response types can be seen in Figure 3.

If the control children produced few transitives overall (including both actives and passives), then it could be argued that they did not interpret the cartoon transitively at the conceptual level. They would then lack the transitive "message" necessary to produce passives. The experimental groups might produce more passives than the controls simply because they received a transitive model that prompted

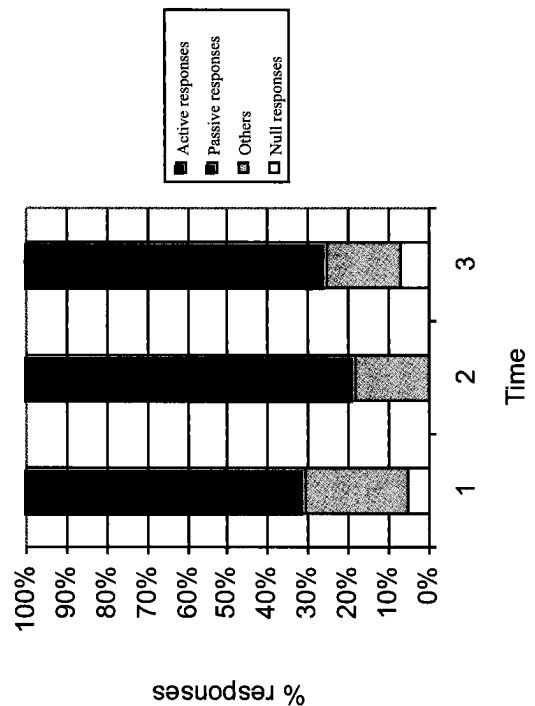
Control Group: The Construction-type of Responses at Times 1, 2 and 3



Group 1b: The Construction-type of Responses at Times 1 and 3



Group 1a: The Construction-type of Responses at Times 1, 2 and 3



Group 2a: The Construction-type of Responses at Times 1, 2 and 3

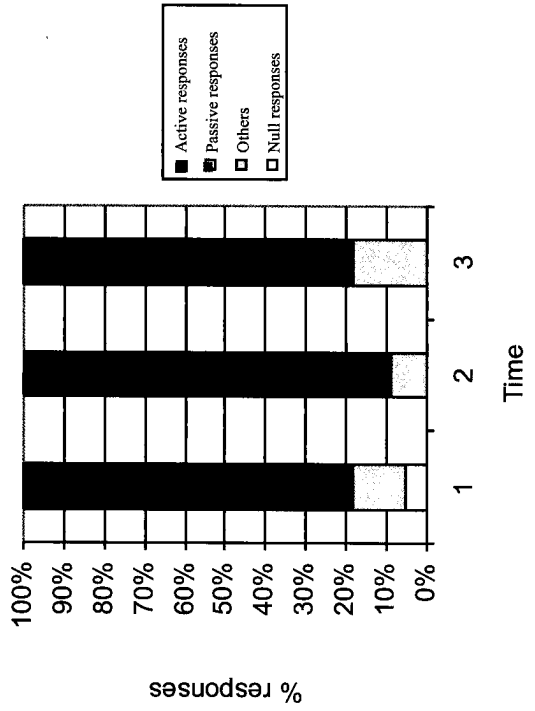


FIGURE 3 Breakdown of responses per group into construction types at each response time.

FIGURE 3 (Continued)

Group 2b: The Construction-type of Responses at Times 1 and 3

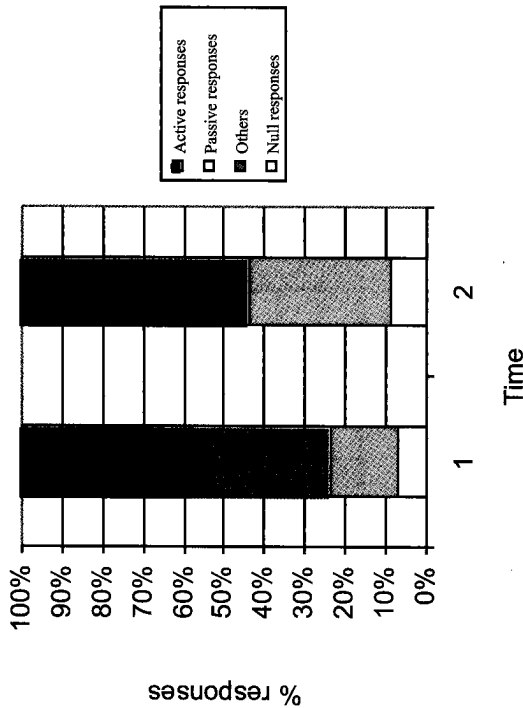


FIGURE 3 (Continued)

them to conceptualize the action-event transitively. If so, any further comparisons between control and experimental groups could reveal spurious priming effects in the experimental groups merely on the basis of an inappropriate comparison.

An inspection of Figure 3 reassures us that the control group does provide an appropriate baseline. It can be seen that the proportions of response types were similar across groups. Most crucially, the spontaneous, unprimed productions of the control group consisted of roughly the same number of overall transitive responses as did the responses of the experimental groups. Certainly, the number of transitives produced by the controls at each time stage was high enough that they could have produced as many passives as the experimental groups.

This was confirmed by the finding that there was no statistically significant difference between the percentage of responses that were transitives in the control condition and those produced in each experimental condition. Nonparametric statistics were chosen over parametric tests because the number of scores in the control group was double that in each experimental group (see Figure 2). A Mann-Whitney *U* comparison was made for each group at each time point. The assumptions necessary for the asymptotic method were not met because the data set was small and unbalanced, so the exact method was used. None of the comparisons were significant (nonsignificant *z* values for control group vs. Group 1a at $T1 = -0.491$, $T2 = -0.140$,

$T3 = -0.846$; nonsignificant *z* values for control group vs. Group 1b at $T1 = -0.392$, $T3 = -0.859$; nonsignificant *z* values for control group vs. Group 2a at $T1 = -1.914$, $T2 = -1.521$, $T3 = -0.622$; nonsignificant *z* values for control group vs. Group 2b at $T1 = -1.779$, $T3 = -2.016$).

Testing the Hypotheses

In each condition, we calculated the percentage of passives produced out of all transitive responses. Passive responses were then analyzed separately at Times 1, 2, and 3, to address the three hypotheses made in the introduction. Nonparametric statistics were chosen over parametric tests because variation in the control group (Group 3) was zero (they produced none). All tests were one-tailed because all hypotheses predicted the direction of the expected effects.

Hypothesis 1. "Does a prime set with high type frequency create a stronger priming effect compared to a prime set involving high token frequency?" Responses produced immediately after primes can be seen in Figure 4.

At T1, the effect of priming was significant for both five identical and five different primes, but it was significantly stronger after five different primes. A single factor, three-level (Groups 1, 2, and 3 responses at T1) Kruskal-Wallis *H* test for independent samples revealed that passive responses produced in each group were not at the same level, $\chi^2(2, N = 66) = 28.083, p < .01$ (one-tailed). A Mann-Whitney pairwise comparison confirmed that all groups were different from each other,

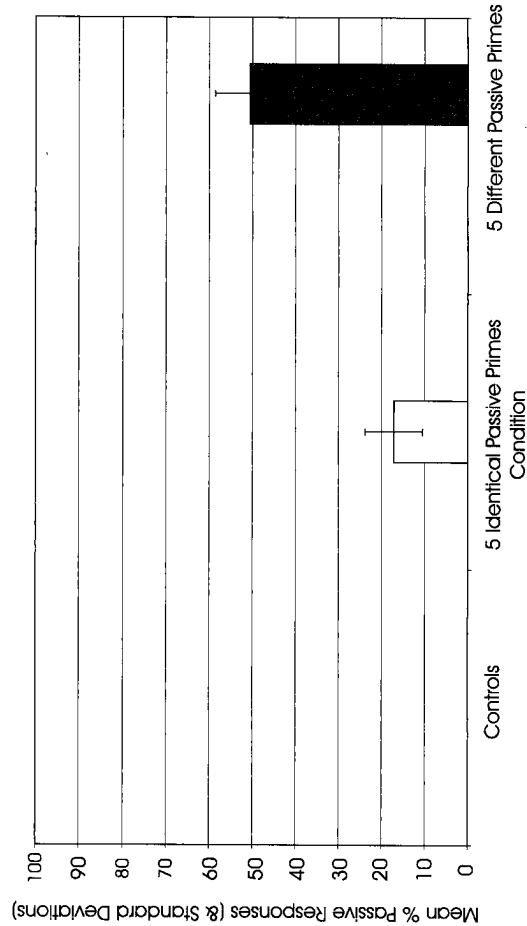


FIGURE 4 Passive responses at T1 as a function of condition.

such that both five identical primes and five different primes produced more passives in comparison with the control group, $z = -2.839, p < .01$; and $z = -5.011, p < .01$, respectively (both one-tailed). On top of this, there was a significant difference between the two priming conditions, with significantly more passives being produced after five different primes than five identical primes, $z = -3.067, p < .01$ (one-tailed). These data support the hypothesis that type variation of the stimuli magnifies the priming effect.

Trials Analysis

The analysis so far supports the hypothesis that high type frequency across the prime set creates a stronger priming effect compared to a prime set without variation. To confirm this, we also looked to see if the effects of priming built up over the five trials within each condition. The numbers of passives produced at Item 1 and Item 5 can be seen below for each group in Figure 5.

We performed two McNemar tests, one for the collective identical primes groups (1a and 1b) and one for the collective varied primes groups (2a and 2b), comparing the number of children successfully primed on Trials 1 and 5 (the con-

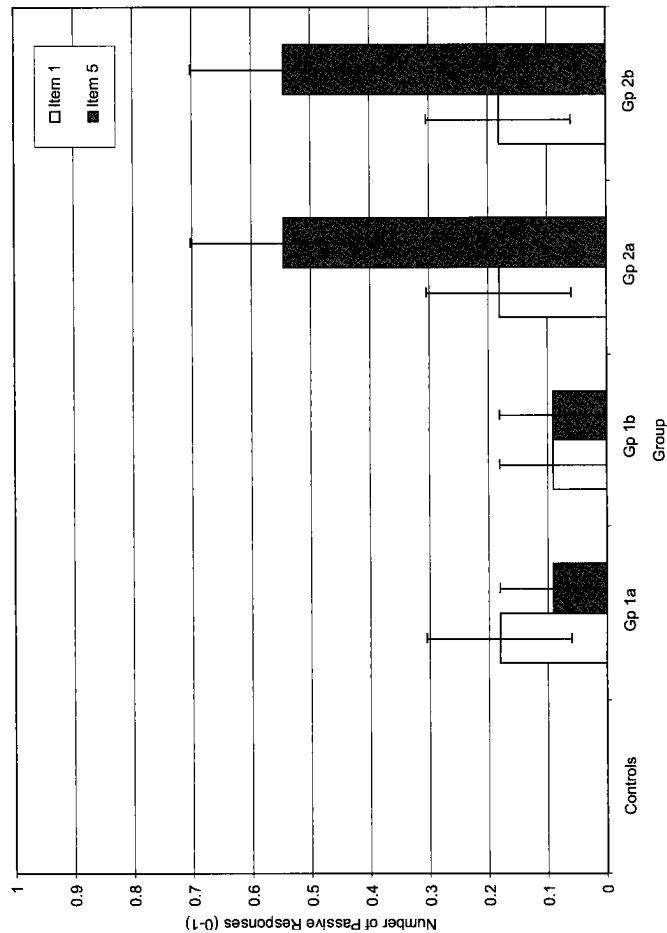


FIGURE 5 Trials analysis for each group.

trol condition excluded because no passives were produced at all)—that is, children producing a passive in one or the other of these trials, both, or neither. The analysis revealed a cumulative priming effect for the varied condition but not for identical primes: More children produced a passive in the last trial than in the first trial in Group 2, binomial $p < .05$, but not Group 1. Moreover, two Wilcoxon signed rank tests revealed no significant difference between the two baselines after Item 1 (nonsignificant z value of -0.447), but significantly more passives were produced in Trial 5 for the varied condition than for the identical condition, $z = -3.162, p < .01$. The findings confirm that the variation across the prime set in Group 2 was responsible for the stronger priming effect these children displayed. They are also supportive of an implicit learning account of priming in that the identical models of the passive would present as much reason for a child to explicitly realize he or she should follow the passive construction in this “game” as would the varied models.

Items Analysis

The results so far suggest that variation across the prime set generates a stronger priming effect. This may be because the lexical variation allows children to discern the more abstract structural regularity shared across the primes. Alternatively, the pattern may be a by-product of the fact that children only used the passive with certain verbs. If so, the varied condition would afford a greater likelihood of those verbs occurring than would the identical condition. Children would only show priming in the latter case if they happened to be able to use the passive with the single verb that they received, whereas in the varied condition there were five different verbs and hence five different chances that they would be productive. To investigate this, in the varied condition, we carried out a verb-wise items analysis to discover whether the data reflect a verb-general priming effect. This analysis concerned the number of passives produced by each child at Times 1 and 3 as a function of verb type. The finding was that priming for a specific verb at Time 3 is predicted equally well by priming at Time 1 on the same verb or a different verb (see Figure 6). This was confirmed by the finding that the Spearman rank correlation between the number of passive responses produced for each of the five verbs at Time 1 and for each at Time 3 was not significant at $p < .05$ ($r_s = -.395$, using the five verbs at Times 1 and 3 as items for the correlation). These data suggest that the priming observed for the varied prime set was indeed at a verb-general level and not due to any one verb.

Hypotheses 2 and 3. “Does the priming effect persist over gaps of 1 week and 1 month?” and “Does priming reinforcement lead to a stronger priming effect after 1 month than when participants receive no targets after a week?” The trajectory of the priming effect across time as a function of priming reinforcement can be seen in Figure 7, which shows responses to targets presented immediately, after 1 week, and after 1 month, along with the control data.

A single factor, three-level (Groups 1, 2, and 3 responses at T2) Kruskal–Wallis H test for independent samples revealed that passive responses produced in each group were not at the same level at T2, $\chi^2(2) = 6.432, p < .05$ (one-tailed). Likewise, a single factor, five-level (Groups 1a, 1b, 2a, 2b, and 3) Kruskal–Wallis H test for independent samples revealed that passive responses produced in each subgroup were not at the same level at T3, $\chi^2(4) = 12.462, p < .01$ (one-tailed). The priming effect was not long lasting for the set of five identical primes. A Mann–Whitney pairwise comparison confirmed that it had decayed after a week, with no more passives being produced after five identical primes than after the neutral condition at T2 and T3, regardless of priming reinforcement (nonsignificant z values = -1.00 at T2, 0.00 at T3 after reinforcement, and 0.00 after no reinforcement).

Interestingly, the priming effect for five different primes persisted up to a week (T2) and even a month (T3) when priming reinforcement was received, with a Mann–Whitney pairwise comparison showing that more passives were produced in both of these conditions compared to the controls, $z = -2.160, p < .05$ (one-tailed) after a week, and $z = -1.821, p < .05$ (one-tailed) after a month, although not without reinforcement (nonsignificant z value = 0.00 at T3). Indeed, there were significantly more passives produced at T3 for five different primes after reinforcement than after no reinforcement, $z = -1.821, p < .05$ (one-tailed).

These results confirm the hypotheses that priming can be long lasting under certain conditions, namely, that the prime set contains variation and that the effect is reinforced by reeliciting target responses after 1 week. This is consistent with the idea that priming, at least in young children, can act as input that leads to implicit learning.

DISCUSSION

The current results confirm the finding of Savage et al. (2003) that 4-year-old children show a sentence-level structural priming effect when there is high lexical overlap between primes and targets. They also extend the previous work in several important directions. Overall, they confirm the hypotheses that both *variation within the prime set* and *priming reinforcement across time* constitute variables that significantly influence the strength and duration of the priming effect. Immediate priming is somewhat effective whether variation in the prime set is present or not, but it is much stronger when variation is present. It is unlikely that this is an artifact of inattention to the repeated identical primes, given that children were required to repeat them themselves on each presentation. Moreover, the priming effect in the varied group is a verb-general phenomenon, and builds up across successive priming trials within the same session. This suggests that it was indeed the variation in the prime set itself that was responsible for the stronger priming effect found in this group, and not simply a by-product of any other property of the

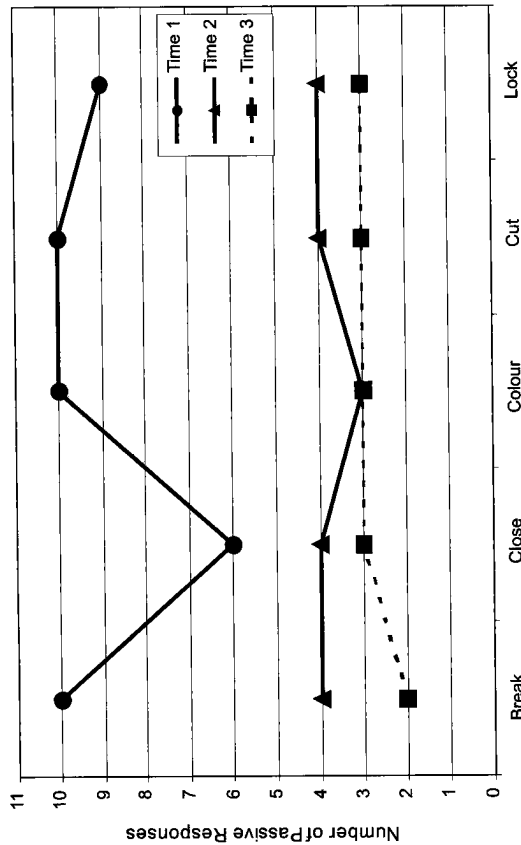


FIGURE 6 Number of passive responses at Times 1, 2, and 3 as a function of verb token.

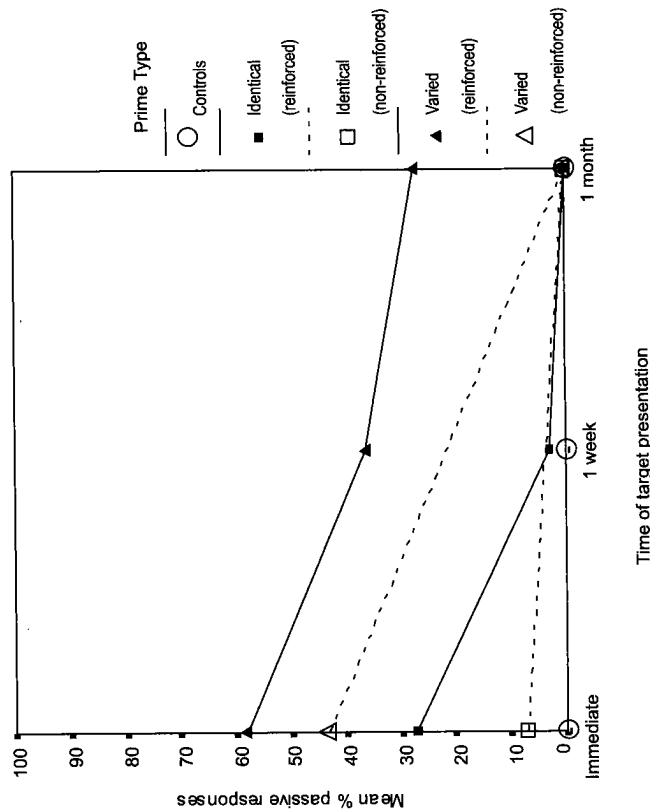


FIGURE 7 Means and passive responses across target presentations as a function of priming reinforcement and prime type.

varied condition. Across time, the priming effect was found to decay fully after a week for identical primes, but to persist for varied primes, again suggesting that children are augmenting their construction representations during the experiment. Priming reinforcement (elicitation of targets) was crucial in maintaining the effect for varied primes over a month-long period.

The overall picture is that both variability and priming reinforcement are significant contributors to the long-term priming effect, although they are not necessary to produce a short-term priming effect. This is consistent with the view that priming can, under certain circumstances, act as input to the child's learning of language. It seems that whether priming becomes implicit learning depends on factors such as variation and reinforcement. With no variation, the effect appears only to be transient, but even with variation, reinforcement is needed to boost the effect over time, and in this case, priming may consolidate into learning. By comparison with the control group, children were more likely to produce passives after both the identical and the varied prime, although after five trials the effect was significantly greater in the varied condition. Although this effect is consistent with an explanation in terms of varied inputs activating the construction especially well, our preferred learning explanation is that children's initial representation of the passive construction is piecemeal (i.e., dependent on lexical items such as *got* and *by* and, perhaps, on particular verbs, for instance *hit*) and less entrenched at an abstract level. Children will therefore be primed to produce a passive to the extent that the prime activates a number of form-meaning mappings that combine together to produce a passive. This is the same for both experimental groups in Trial 1 and, indeed, levels of priming are the same for both groups in Trial 1. However varying the primes strengthens a more abstract and schematic representation of the passive and thus affords the production of significantly more passives by the end of Trial 5. Given that the children in the Huttenlocher et al. (2004) study were only 6 months older than the present children, our claim would be that children between 4;0 and 5;0 are consolidating their schematic representation of the passive and that, under certain circumstances, small amounts of input can make a considerable difference to the linguistic representation that underlies production.

We will first consider the effect of variation. In the varying primes condition, variation occurred in the verb slot across primes within a consistent frame, "It got Ved by it." It was predicted that the variation within the slot position would serve to highlight the surrounding frame, such that children could identify the surrounding schema; a prediction that the current results support. More important, the finding that variation across the prime set creates a priming effect, rather than only the relation between one prime and one target, suggests that the priming effect reflects a learning process. This would be difficult to explain if priming were merely the transient activation of an abstract form on the basis of a single prime. It is also unlikely that the data reflect a sort of explicit learning concerning how to play a game with the experimenter in which pictures were described using passive syntax. This

is because there is no reason to expect that this form of learning would differ between the two conditions of varied and identical primes. The identical models of the passive would present as much reason for a child to explicitly realize they should follow the passive construction in this "game" as would the varied models. It seems fair to conclude that the effect observed for the varied condition is indeed a form of implicit learning.

The current findings fit well with usage-based theories of acquisition that invoke "schematization" as one of the major mechanisms for learning and abstraction in language acquisition (cf. Tomasello, 2003). Schematization relies on systematic variation within a consistent frame to create a more abstract schema (Childers & Tomasello, 2001; Theakston, Lieven, & Tomasello, 2003; Tomasello, Akhtar, Dodson, & Rekau, 1997), and evidence for the use of such schemas has been found in the naturalistic speech of a 2-year-old child, "Annie," by Lieven, Behrens, Speares, and Tomasello (2003; see also, Braine, 1976; Lieven, Pine, & Baldwin, 1997; Pine, Lieven, & Rowland, 1998). The process of abstraction relies on variation because without it a child cannot recognize the commonalities among the various exemplars that fill the slot (in the current case that they are all verbs) and so would fail to build an abstract slot. Repeated exposure to a single concrete example could not support this process because there would be no grounds for abstraction, only for learning a concrete, unanalyzed chunk (cf. Bybee, 1995). The current data support this model by showing that variation adds something extra to the priming effect in comparison with the nonvarying group:¹ It is stronger in the first testing session and persists across time rather than decaying.

To date, the adult syntactic priming literature has yet to explore the role of variation in the distinction between priming and implicit learning with adults. They all use varied primes, but the results of the adult studies do not break the data down across trials. They measure globally the total number of target sentences that are produced using primed constructions, and so any cumulative effect across trials would be masked. It is possible that even in the adult data the effect of priming is greater in later trials than in earlier ones. It would be interesting to ascertain whether priming is effective or weaker in adults in the absence of variation. If adults do indeed access a fully abstract representation of the construction and are primed on this basis, then our prediction would be that, unlike children, they should not show a difference in priming as a function of the same or varying primes.

The second major finding of this study is that the priming effect can persist across time even longer than has yet been found for adults (e.g., Bock & Griffin, 2000) or for children (Huttenlocher et al., 2004). After varying primes, the effect persisted reliably across an interval of 1 week without systematic priming rein-

¹The five identical primes could not be expected to lexically prime the specific sentence used because the target verb always differed from the prime.

forcement and up to a month if reinforcement was provided by repeated exposure to targets at the 1-week stage. Two possibilities could explain this result. The effect could decay equally over time with and without variation in the prime set, but the effect of the identical primes dropped below the threshold of significance because it was smaller in the first instance, or the variation in the prime set consolidated the passive construction more in the children's memories and so decayed at a slower rate. More detailed investigation targeted specifically at this facet of the priming effect would be needed to determine this. In any case, the current results clearly show that the effect is long lasting when variation is present, consistent with an implicit learning explanation in this condition.

The effect of priming reinforcement brings to light the interesting possibility that the priming effect was maintained by "self-priming" during the intervening period. If children's use of the syntactic structures that they had received increased as a result of input in Session 1, then their own productions could serve as further input, such that their use of the primed constructions was maintained. Consistent with this hypothesis is the finding that the priming effect was maintained up to a month only when targets were presented again at 1 week, and without this the number of passive responses produced after a month decayed back to zero. This can be explained by the fact that the effect of priming for passives was still present for targets presented after 1 week, so the presentation of targets at this stage prompted children to produce more passives. In effect, each target became a new prime, increasing the frequency of the target construction over time.

It would be desirable to tease apart the contributions of implicit learning from the original primes and the effect of self-priming. Further investigation is needed to determine what conditions are necessary for the effect to persist. One possibility would be to contrast an intervening period that is filled by syntactically unrelated items with a period of silence (although the latter may prove difficult with young children and would need to be short). In light of the adult data (Bock & Griffin, 2000; Branigan, Pickering, Stewart, & McLean, 2000) it would be expected that the priming effect would persist across both of these gaps, but it is possible that it would not if self-reinforcement were the only factor that promoted the persistence of the effect in the current design. To investigate further, it would be interesting to compare how the priming effect endures across a controlled half-hour gap filled with distracters with one filled by free speech, for which the recurrence of the primed structure could be monitored. Another line of inquiry would be to manipulate different "massing" and "spacing" of the stimuli, to determine whether the reinforcement effect observed in the current design depends on when the children receive further target items or on the fact that children in the reinforced group received more targets per se. It would be interesting, for example, to compare the effect of giving children the target reinforcement after a week, as in the current design, with presenting the same overall number but in one single block, as in the first stage of priming (i.e., immediately after the primed trials).

The current results have interesting implications for real-life acquisition. In a learning context, children interact with interlocutors, so the "self-priming" process would not function in isolation. It has been well established experimentally that small speech communities coordinate their language productions at the semantic and lexical levels, using both adults (Brennan & Clark, 1996; Garrod & Anderson, 1987; Garrod & Doherty, 1994; Schober & Clark, 1989) and children ages 7 to 12 years (Garrod & Clark, 1993). More recently, Branigan, Pickering, and Cleland (2000) established such dialogue coordination skills at a syntactic level, suggesting that over time, dialogue coordination promotes the use of certain linguistic schemas above others, such that a shared set of dominant schemas emerges between the speakers. Most interestingly, Branigan et al. (2000) interpret their findings as constituting an instance of syntactic priming in a dialogue context. Each interlocutor would be primed by the other's choice of construction, such that reciprocal priming would promote the use of certain forms over others.

Given this evidence, it could be predicted that priming in acquisition would also be strengthened by a dialogue context. Children would receive two forms of input, that from others and that from themselves, and moreover the two sources would interact to promote the occurrence of the primed structure. The existing dialogue research suggests that this process would increase the frequency of a construction and promote its acquisition by children. It is worth mentioning also that although context effects were minimized in this study by using different target pictures at each stage, in real-life learning these could be involved positively as another boost to syntactic frequency, by increasing the use of a certain construction in certain situations, such as games or books. It would be very interesting to conduct dialogue coordination experiments similar to those with adults with groups of young children or young children and adults. It would also be useful to search for this effect in naturalistic data of parent and child interactions by tracing the patterning of certain syntactic frames to establish whether they occur in clusters and whether this has any effect on children's learning.

We should perhaps acknowledge in closing that one might possibly interpret the current results not in terms of learning during the priming experiment, but rather in terms of children's increased access to an already learned construction. However this interpretation requires a somewhat different definition of priming than is typical in the literature, as priming is traditionally thought to be transient, and we have found very long-lasting effects. There is some merit to the "increased access" proposal because we certainly do not think that children are learning the passive construction in our study from nothing; we think that for the experiment to work they had to know something about this construction before the experiment began. Therefore, we think that the current results provide evidence both for a transient priming effect of an already partially abstract construction and for augmentation of the representation of that construction (i.e., learning) over the course of the experiment—perhaps in the direction of increasing abstraction.

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