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The Primacy of Priming in Grammatical Learning and Intervention: A Tutorial

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Abstract

Purpose—The author presents a tutorial on structural priming and its relevance to the study of grammatical development and language intervention.

Method—The findings from structural priming studies are examined from the standpoint of the types of changes that occur in participants' language use, the contexts in which these changes occur, and the effects of these changes on participants' language knowledge. Details of children's grammatical development and language intervention are then considered in light of these findings.

Results—Evidence from the structural priming literature provides insight into the transition from early conservative grammatical use to broader abstract grammatical use in young children, and suggests ways in which language intervention activities can be modified to promote greater grammatical change in children with language impairments.

Conclusions—Structural priming is not divorced from everyday language use. Evidence from priming research can be put to use in the study of children's grammatical development and in shaping the methods that are used to facilitate children's grammatical abilities.

Introduction

Since the mid 1980s, many studies in the language sciences have examined the phenomenon of "structural priming". These studies show that the sentences produced by speakers are influenced by the sentences that they had just heard. This influence is seen even when the speakers' productions do not contain the same words or thematic relations that appeared in the preceding sentence. For example, after hearing a sentence such as *The man bought the candy for his children*, a speaker is more likely to describe a picture with the sentence *The girl gave the bicycle to the boy* than with the sentence *The girl gave the boy the bicycle*. Here, the sentence heard by the speaker is referred to as the "prime sentence" and the sentence produced by the speaker is the "target sentence". Of special note is the fact that, in this example, the speaker's description of the picture (the target sentence) has the same syntactic structure as the prime sentence, yet the nouns, the verb, and even the preposition differ from those that appeared in the prime sentence. The purpose of this tutorial is to demonstrate that many key principles in the structural priming literature translate quite directly to the study of children's grammatical development as well as to language intervention with children.

Structural Priming

Structural priming can be distinguished from semantic priming and phonological priming. Semantic priming is seen, for example, when research participants' picture naming times are

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much faster if they had just heard a word from the same semantic category (e.g., animals) as the picture to be named. Phonological priming is seen when, for example, a picture of an object (e.g., train) is named more quickly when participants hear a word with the same onset (e.g., *tree*) than when they hear a word with a different onset (e.g., *clock*) at the time the picture to be named is presented. Structural priming, the focus of this tutorial, refers to the influence that a prior sentence can exert on the syntactic structure that participants select, apart from any effects attributable to semantic or phonological factors.

The Prototypical Structural Priming Paradigm

Although structural priming has been observed in early studies of conversations and interviews (Schenkein, 1980; Weiner & Labov, 1983), the now-classic structural priming paradigm is the one first employed by Bock (1986). In the Bock study, adult participants heard and repeated sentences (the primes) and then described target pictures that were semantically unrelated to the primes. The task was devised so that the participants were not aware that the structure of their picture descriptions was under investigation. Initially, the participants were asked to look at pictures and listen to sentences that they would be asked to recognize at a later point. Subsequently, along with responding with a "yes" or "no" during the recognition phase, they were also asked to repeat the sentences (the primes) and describe the pictures (the targets). The arrangements of the sentences to be repeated and the pictures to be described enabled an examination of the priming effects. The primes were transitive sentences in either active (e.g., *A janitor cleans the floor daily*) or passive voice (e.g., *The floors are cleaned by a janitor daily*), and dative sentences with either a prepositional phrase (e.g., *The waitress took a tray of appetizers to the customers*) or a double object (e.g., *The waitress took the customers a tray of appetizers*). The target pictures could be described using either of the alternative structures (active or passive; prepositional dative or double object dative). Bock found that the participants' actual descriptions clearly reflected the influence of the particular structure that had appeared in the prime. The participants showed no awareness that the structures used in their picture descriptions were a focus of the investigation.

Initially, structural priming was viewed as an ephemeral event strictly associated with language performance. It was assumed that when a prime sentence was produced, the syntactic structure of the prime remained in a temporary state of activation. When a subsequent (target) sentence whose message was compatible with the structure of the prime was then formulated, the already-activated structure of the prime rendered it more readily retrievable, increasing the likelihood that the structure adopted for the target sentence was the one reflected in the prime. As will be seen later, this characterization of structural priming is now viewed as too narrow by some investigators.

What Type of Linguistic Information is Primed?

Since Bock's (1986) influential study, much more has been learned about the nature of structural priming. (For a recent and highly informative review, see Pickering & Ferreira, 2008). The operational level of priming – the level of abstraction that appears to be affected by priming – is roughly the level captured by phrase structure notation, as in Noun Phrase – Verb – Noun Phrase – Prepositional Phrase (hereafter, NP V NP PP). For example, Bock and Loebell (1990) showed that a picture description with a prepositional dative such as *The man handed a pitcher to the woman* could be primed by either a preceding prepositional dative (e.g., *The wealthy widow gave an old Mercedes to the church*) or a preceding prepositional locative (e.g., *The wealthy widow drove an old Mercedes to the church*). These two prime types share a prepositional structure but differ in terms of their thematic relations (dative versus locative). In some linguistic accounts, both datives and locatives are considered to be goal arguments, and hence not strikingly different in their thematic

characteristics. For this reason, Bock and Loebell conducted another experiment in which alternative prime sentences with similar structure were dramatically different in the thematic relations they portrayed. In this experiment, both passives involving a prepositional phrase (e.g., *The minister was cut by the broken stained glass window*) and locative adjuncts involving a prepositional phrase (e.g., *The minister was praying by the broken stained glass window*) successfully primed picture descriptions of a passive construction, as in *The man was stung by a bee*).

These findings seem properly attributable to priming at a phrase structure level rather than to influences of a more superficial nature. Bock and Loebell (1990) included an experiment that compared the priming effects of prepositional datives such as *Susan brought a book to Stella* and sentences with an infinitival complement such as *Susan brought a book to study*. Although these two sentences show lexical overlap and are matched on number of syllables, they differ in their structure. As expected, prepositional dative primes increased the likelihood that participants would describe target pictures with prepositional datives. However, primes with infinitival complements exerted no influence on the participants' choice of dative constructions.

Studies of bilingual participants also provide support for the view that the elements influenced by priming are rather abstract and phrase-structure-like. Loebell and Bock (2003) found that primes presented in one of the participant's languages influenced his or her picture descriptions in the other language. This priming occurred in the absence of cognate words in the two languages; the relevant factor was whether the structure reflected in the prime (in one language) was also appropriate for describing the target picture (in the other language).

Clauses within sentences can also be primed. For example Branigan, Pickering, McLean, and Stewart (2006, Experiment 6) found that priming of a simple sentence containing a prepositional dative or double object dative occurred even when the prime was a complex sentence containing the prepositional dative or double object dative in the subordinate clause (e.g., *The paper claimed that the student loaned the friend the money*). These and related findings led Branigan et al. to propose that local or smaller syntactic structures are responsible for the priming effects. In their review of the structural priming literature, Pickering and Ferreira (2008) suggested that the units subject to priming are, roughly, proposition-sized units at the phrase structure level.

Structural priming at the phrase structure level also seems to occur even if the prime is an idiom. For example, Konopka and Bock (2009) found that a prime such as *The cop dug in his heels*, in which the verb particle (*in*) immediately followed the verb, could increase the likelihood that a target sentence would be formulated with the same structure (e.g., *The cat knocked over the vase*) as opposed to an equally acceptable alternative structure (*The cat knocked the vase over*). Despite the fact that idioms constitute special word combinations that have their own meaning, the syntactic structures reflected in these idioms also have an influence on individuals' sentence formulations.

Priming as Implicit Learning

As noted earlier, priming used to be viewed as a strictly production-related phenomenon, where a primed structure made speaking more efficient through activation that was presumed to be quite transient in nature. However, some investigators now view structural priming as a process that constitutes a type of implicit learning, whereby priming influences language knowledge. That is, priming seems to serve the function of strengthening mappings between meanings and linguistic structures. There are several sources of evidence for viewing priming as much more than transient activation. First, priming effects persist

even when intervening material appears after the prime sentence and before the target picture is presented. This was first demonstrated by Bock and Griffin (2000), who found that prepositional datives such as *The driver sheepishly handed his license to the police officer* served as primes for target picture descriptions (e.g., *The boy gave an apple to the teacher*) even when as many as 10 unrelated sentences (e.g., *The books were expensive*) intervened between the prime sentence and the presentation of the target picture. Subsequent investigations showing structural priming effects with unrelated material intervening between primes and targets include the studies of Konopka and Bock (2005), and Hartsuiker, Bernolet, Schoonbaert, Speybroeck and Vanderelst (2008).

Another form of evidence consistent with the learning view of priming comes from the observation made by Ferreira and Bock (2006) that the particular structures that show the largest priming effects in the literature are those that are less common or less preferred relative to alternative structures. This pattern in the findings would be compatible with the idea that material that is less well known should be subject to greater learning than material that is quite well known.

Ferreira, Bock, Wilson, and Cohen (2008) provided rather strong evidence for the implicit nature of priming effects. These investigators studied four adults with anterograde amnesia along with four adults serving as controls. Individuals with anterograde amnesia have severe deficits in their ability to encode new information and thus are very poor at recalling recent events. Ferreira et al. found that the individuals with amnesia, like their controls, showed structural priming effects when describing target pictures (even when 10 filler sentences intervened between the prime and the description of the target picture). However, when tested on their recognition memory of the prime sentences, the individuals with amnesia were much less accurate than the control participants. Most errors by the control participants were cases in which they incorrectly identified foils that matched the prime in meaning but not syntactic structure. Individuals with amnesia, on the other hand, made errors in recognition even when the foils different from the prime in meaning. These findings suggest that structural priming can occur when recollection of the prime sentence is confined primarily to its meaning or, in the case of amnesia, there is no recollection of the prime sentence at all.

Chang, Dell, and Bock (2006) employed a computational model to study long-term effects of structural priming to determine the plausibility of priming as grammatical learning. Prime-target pairs were presented to the model, and the model was allowed to adapt as it continued to generate sentences. The results appeared to simulate most of the findings in the structural priming literature, including the generation of new sentences over time that seemed to reflect long-term learning effects.

The implicit learning view of structural priming is not universally held. Pickering and Branigan (1998) view structural priming as short-term activation of a structure. As we soon note, this view may be especially useful in explaining the priming that occurs when the prime and the target sentence share some of the same material.

The Lexical “Boost”

Along with the compelling evidence for the phrase structure level of priming effects, there is evidence of lexical effects playing an augmentative role in priming. Pickering and Branigan (1998) found that when the prime and the target sentence shared the same verb, priming effects were especially strong. The fact that priming also occurs when there is no lexical overlap suggests that lexical factors are not the driving force behind priming but rather provide an additional “boost” to the priming effect (Pickering & Ferreira, 2008).

There is now considerable evidence that the lexical boost is short-lived (e.g., Hartsuiker et al., 2008; Kaschak & Borreggine, 2008; Konopka & Bock, 2005). This is seen when the effects of prime-target pairs sharing the same verb are compared to the effects of prime-target pairs involving different verbs. When the prime immediately precedes the target, priming effects are stronger when the same verb is employed than when the verbs in the prime and target are different. However, when several unrelated sentences intervene between the prime and target, the priming effects for pairs involving the same verb are no stronger than the effects for pairs involving different verbs.

At least two explanations have been offered for the co-existence of verb-specific effects and structural priming. Each explanation has its advantages, though they seem to differ in how well they can account for the shorter duration of the lexical boost relative to the longer-term effects of structural priming.

The first explanation was offered by Cleland and Pickering (2003; see also Pickering & Ferreira, 2008). These investigators proposed that the association between a specific verb and the other sentence elements (e.g., *give* with NP PP) in a speaker's experience creates a combinatorial link between them that co-exists with the more abstract structure (e.g., V NP PP) that reflects the speaker's knowledge of the shared structure that the specific verb enters into along with other verbs. This shared structure is responsible for priming when the prime sentence and target involve different verbs. However, when the prime and target involve the same verb, priming occurs through both the shared structure (V NP PP) and through the link between the specific verb and the other elements of this structure (*give* NP PP). Although this approach provides a clear explanation for the lexical boost, it is less clear how it can explain the short-term effects of this boost relative to the longer-term effects of structural priming.

A second explanation has been provided byChang et al. (2006). These investigators assume that both verb-specific combinatorial effects as well as broader structural effects co-occur during learning. However, to account for the brief duration of the lexical boost, they also assume a role played by explicit memory. Specifically, when the verb in the target matches the verb in the prime, the repeated verb serves as a cue for the explicit memory of the wording of the prime. This memory, in turn, biases the speaker to repeat the structure of the prime when producing the target sentence. Because explicit memory is of short duration, its effects are transient. However, although the lexical boost is temporary, it is assumed that both verb-specific and broader structural information is retained and contributes to learning.

Priming through Listening

Subsequent research has shown that the syntactic structures produced when describing target pictures can also be primed simply by listening to prime sentences. For example, Bock, Dell, Chang, and Onish (2007) found that listening to passive primes such as *The car's windshield was struck by a brick* resulted in a greater tendency for adult participants to describe pictures with a passive (e.g., *The boy is awakened by a noisy alarm*). It seems unlikely that the priming effects were facilitated by covert rehearsal of the structures in the prime sentences because Bock et al. found that the priming effects persisted even when participants listened to several filler sentences (e.g., *The real-estate agent blundered*) prior to being presented the target picture to describe.

These findings of priming through comprehension demonstrate that the prime sentence does not have to be produced to have an influence on the structure of the target sentence. An investigation by Melinger and Dobel (2005) suggests that the full structure of a prime may not even have to be heard to have the same type of influence. In a study using German and Dutch (in separate experiments), Melinger and Dobel took advantage of the fact that some

verbs permit only one structure even though other verbs with similar meanings allow for alternative structures. For example, in English, the verb *contribute* allows for a prepositional dative structure, as in *The attorney contributed two thousand dollars to the Firefighters Fund* but not a double object dative structure, even though both structures can be used with other verbs (e.g., *give*) that convey similar meanings. Melinger and Dobel selected verbs that allowed for only a prepositional dative or only a double object dative structure. They presented these verbs in isolation to participants who read each verb silently and then described a picture. The depicted action required a verb that allowed for a description with either a prepositional dative or a double object structure. The participants' choice of structure in their picture descriptions was clearly influenced by the (unique) structure associated with the verb in isolation that they had read just prior to describing the picture. This finding suggests that all elements in a structure do not have to appear in a prime, provided that the verb in the prime has been associated with only one structure in the participant's linguistic experience.

The studies discussed thus far have assessed priming effects through participants' sentence production. Studies of priming effects on sentence interpretation are also beginning to appear. Some of these studies have examined participants' interpretation of potentially ambiguous sentences. Branigan, Pickering, and McLean (2005) found that ambiguous sentences were interpreted in a manner that was consistent with the structure and interpretation of the sentences appearing in the prime. Ledoux, Traxler, and Swaab (2007) reported similar findings using event-related potentials (ERPs). However, in these studies, priming seemed to be limited to prime-target pairs that shared the same verb.

Thothathiri and Snedeker (2008a) employed a visual world eye-gaze paradigm to examine comprehension-to-comprehension priming. After hearing primes in either a double object dative (e.g., *Send the frog the gift*) or prepositional dative (e.g., *Send the gift to the frog*) structure, the participants acted out a target sentence with toys. Cleverly, the structure of the target sentences could not be distinguished until well into the first noun. For example, in *Now you can give the camel the brush* and *Now you can give the camera to the shark*, the participants could not know which structure was used in the target until well into the word *camel* or *camera*. If the structure of the prime sentences were influencing the participants' comprehension, their looking times toward the first noun reflecting the primed structure during the ambiguous period should be greater than toward the first noun reflecting the alternative structure. In the example used here, if the double object dative structure were used in the prime sentences, greater looking time should be seen for the camel, even during the early portions of the word *camel* when there was insufficient information to distinguish *camel* from *camera*. The results were in keeping with these expectations. Because the verbs and nouns used in the primes and targets were different, this investigation provided important evidence for priming at a relatively abstract, structural level.

Priming in Dialogue

Many of the priming effects observed within the classic priming paradigm can also be seen in dialogue (Branigan, Pickering, & Cleland, 2000; Cleland & Pickering, 2003). In this context, the participants respond to their interlocutors' comments with their own message. Thus, the structural influences seen in these studies resemble those seen in the comprehension-to-production priming studies described earlier. However, structural priming in dialogue can also reveal a social communicative dimension. Branigan, Pickering, McLean, and Cleland (2007) found that participants were more likely to be influenced by the structure of an interlocutor's sentence if that sentence had been directed at them than if it had been directed at a third participant in the conversation.

Gries (2005) examined priming effects reflected in a very large corpus of British English. Although information about the social and communicative goals of the speakers do not permit this study to be considered an investigation of dialogue, priming effects from one speaker to the next were clearly evident for the prepositional dative/double object dative alternative structures and for the verb + particle + noun/verb + noun + particle alternative structures. Gries also found that these priming effects were detectable even when multiple utterances intervened between the prime and the target. Priming was also stronger when prime and target shared the same verb. Interestingly, specific-verb effects were seen even when unrelated utterances appeared between the prime and the target. Such an observation is an exception to the more common finding of a short-lived lexical boost.

Structural Priming with Children

Studies of structural priming in children are beginning to appear in the literature. Huttenlocher, Vasilyeva, and Shimpi (2004) employed a structural priming task with four- and five-year-old children. The children heard and repeated the experimenter's picture description and then described a different picture that could be described with the same structure. This presentation of prime-target pairs continued for 20 trials. For 10 of the trials, the child heard and repeated active or passive sentences (e.g., *The truck hit the house* or *The house was hit by the truck*); for the remaining 10 trials, the child heard and repeated prepositional dative or double object dative sentences (e.g., *The man is showing a rock to the children* or *The man is showing the children a rock*). The target pictures were designed to invite verbs that differed from those of the preceding prime. Huttenlocher et al. found clear priming effects for each of the structures that were primed. Given that there was little or no lexical overlap in the prime-target pairs, Huttenlocher et al. concluded that priming was operating at a syntactic (phrase-structure-like) level.

In studies of adults, structural priming occurs even if participants simply listen to the prime. To determine whether the same was true for four- and five-year-olds,Huttenlocher et al. (2004) repeated their first experiment but had the children listen to but not produce the prime sentences before describing the target pictures. Again, clear priming effects were seen for each of the structures that were primed. In a third experiment, Huttenlocher et al. had the children listen to 10 consecutive prime sentences of the same structure (e.g., double object dative) and then describe 10 consecutive target pictures that could be described by the same (or the alternative) structure. This procedure was repeated for the other structure to be primed (e.g., passive). Priming effects were again observed for each structure primed. Furthermore, the children's tendency to use the primed structure did not decrease from the first five picture descriptions to the second five picture descriptions, suggesting some durability in the priming effect.

Shimpi, Gámez, Huttenlocher, and Vasilyeva (2007) conducted a similar investigation with three- and four-year-olds. They found that four-year-olds showed priming effects after only hearing the prime sentences, but three-year-olds showed no evidence of priming unless they also repeated the prime sentences.

Other priming studies have found that priming occurs with three-year-olds but only when there is considerable lexical overlap between prime sentences and target sentences (Savage, Lieven, Theakston, & Tomasello, 2003); by four years of age, the evidence for priming at more abstract levels of structure seems to be stronger (Savage, Lieven, Theakston, & Tomasello, 2006). More recently, Bencini and Valian (2008) found evidence for priming effects in three-year-olds when the verbs in the prime and target sentences were different.

The use of new paradigms may offer additional evidence of structural priming in young children. Thothathiri and Snedeker (2008b) employed the visual world eye-gaze paradigm

with both three-year-olds and four-year-olds. As in their study with adults described earlier (Thothathiri & Snedeker (2008a), these investigators used target sentences that could not be distinguished on structural grounds until well into the first noun of the sentence, as in *Give the doll the cat food/Give the dollhouse to the bunny*. Both age groups showed priming effects. For example, for children hearing prime sentences with prepositional datives, looking times were longer for the dollhouse, even during the early part of the word *dollhouse* when there was insufficient information to distinguish *dollhouse* from *doll*. These effects were seen even when the verbs used in the prime and target sentences were different, though effect sizes were larger for same-verb priming than for across-verb priming.

Some priming studies have included preschool-aged children with specific language impairment (SLI) as well as typically developing peers. Miller and Deevy (2006) examined the effects of transitive prime sentences (e.g., *The dog's licking the baby*) and intransitive prime sentences (e.g., *The dog's barking*) on the children's descriptions of target pictures that could be described appropriately with either a transitive sentence (e.g., *The mouse is reading a book*) or an intransitive sentence (e.g., *The mouse is reading*). Both the typically developing children and the children with SLI were more likely to describe the target pictures with transitive sentences if the prime sentence was transitive than if the prime sentence was intransitive. These effects were seen even though the verbs in the prime and target sentences were different.

Leonard, Miller, Grela, Holland, Gerber, and Petucci (2000) also studied priming effects in both preschoolers with SLI and typically developing children. These investigators asked whether priming could influence the degree to which children produced rather than omitted an auxiliary *be* form in their target picture descriptions. All children recruited for this investigation were inconsistent in their use of auxiliary *is*, sometimes omitting this morpheme in obligatory contexts (e.g., *Daddy working*). Given that children with SLI are well below age level in their use of grammatical morphology, matching the two groups for degree of auxiliary *is* use necessarily resulted in age differences between the SLI and typically developing groups. The children with SLI averaged five years of age; the typically developing children averaged three years of age. Leonard et al. asked whether the children were more likely to include (rather than omit) auxiliary *is* in their target picture descriptions if the preceding prime sentence included an auxiliary form (e.g., *The boys are washing the car*) than if the prime sentence did not have an obligatory context for an auxiliary (e.g., *The pig fell down*). Both groups of children showed clear priming effects, producing auxiliary *is* (e.g., *The horse is kicking the cow*) more frequently in their target picture descriptions if the prime sentence contained an auxiliary. This finding held even when the particular auxiliary forms in the prime and the target were different.

In summary, the evidence from priming studies with children makes it clear that children's sentence productions (and possibly their interpretation of sentences) are subject to priming. At the youngest ages, priming effects may depend somewhat on shared verbs across prime and target sentences. However, by four years of age, priming effects that reflect the influence of broader abstract structures are readily apparent. These conclusions should be tempered somewhat by the fact that priming studies with children have employed a more limited range of experimental designs than studies with adults. For example, filler sentences are often used with adults to observe longer-term effects between the prime and target sentence. In children, the durability of priming has only been measured by comparing effects on target sentences produced by the child immediately after the prime or several sentences later. In addition, in studies with adults, priming effects can be compared on a within-subject basis, as each participant is tested using primes of each alternate structure. In studies with children, comparisons tend to be between different groups, each assigned to a different priming condition.

Priming and Children's Grammatical Development

The implications of structural priming in children go beyond the demonstration of priming effects in the laboratory. Structural priming may lie closer to the heart of grammatical learning than previously assumed.

Grammatical Development and Structural Priming: Some Parallels

For researchers who assume strong input effects on children's learning of grammar, the parallels between structural priming and grammatical development are quite clear. These investigators have provided considerable evidence that the grammatical forms noted in young children's speech are found to occur quite frequently in the input (see Tomasello, 2003). Of course, the scenario of learning language under typical circumstances hardly matches the controlled conditions under which priming is usually investigated. However, acquiring grammatical structures through hearing them frequently in the input certainly approximates the comprehension-to-production priming reviewed earlier. Furthermore, priming effects are seen even when there is linguistic material that intervenes between the prime and target. Thus, a child's use of an input-induced structure need not occur immediately after the sentence(s) that influenced it. In addition, as in language learning under natural conditions, priming seems to involve implicit learning, where input effects are seen often without the participant having recall of the influencing linguistic material. There is yet another parallel. Structures are acquired by children in a social communicative context. Scholars who have examined priming in the context of dialogue might have a similar view about structural priming. Recall that priming effects are stronger for sentences directed at the participant than for sentences directed at another participant in the conversation.

Finding the Connection between Early Verb-Specific Patterns and the Lexical Boost

There may be one additional parallel between structural priming and grammatical development: The verb-specific effects seen in the well documented "lexical boost" during structural priming bear a similarity to children's use of verb-specific patterns during the early period of grammatical development. However, there may be differences between these two phenomena that should be reconciled before the parallel is viewed as more than coincidental. In structural priming, verb-specific effects (the lexical boost) occur alongside structural priming and actually strengthen the priming effects relative to those seen for structural priming alone. On the other hand, this lexical boost in priming has a short duration, unlike structural priming effects. In contrast, one view of the verb-specific patterns seen in children's early grammatical development is that they predate the appearance of broader, more abstract structures (e.g., Tomasello, 1992; Lieven, Pine, & Baldwin, 1997). For example, a young child might use the verb *throw* only in a dative structure such as *Throw me ball* but use the verb *give* only with a different dative structure, as in *Give ball to daddy*. These patterns appear to be directly tied to a child's input history. Furthermore, when verbs begin to be used in a common manner, the verbs that enter into this shared structure are those that appear in this structure most frequently in the input (Campbell & Tomasello, 2001).

The verb-specific effects in young children's utterances have also been seen in laboratory studies. For example, Akhtar (1999) studied English-speaking children two-, three-, and four-years of age. The children heard multiple exemplars of three novel verbs, each associated with a particular transitive action and each used in a single word order, either subject-verb-object (e.g., *Elmo dacked the car*), subject-object-verb (e.g., *Elmo the car gopped*), or verb-subject-object (e.g., *Tammed Elmo the car*). After this exposure period, the children were asked to describe events involving the same actions. The two- and three-year-

olds were significantly influenced by the structure in which the novel verb was heard, as they often produced the novel verb with this same structure, even when it was uncharacteristic of English. The four-year-olds, in contrast, used all of the novel verbs in the subject-verb-object order, regardless of the structure in which the novel verb was heard. Similar findings have been reported by Abbot-Smith, Lieven, and Tomasello (2001) and by Matthews, Lieven, Theakston, and Tomasello (2005).

The presence of verb-specific patterns in early grammatical development seems indisputable. However, the assumption that they predate children's knowledge of broader abstract structures may be debatable. If verb-specific patterns co-exist with knowledge of broader structures, the parallel between priming and grammatical development would be stronger. In fact, a case can be made that verb-specific patterns may co-exist with, rather than precede broader structural knowledge in children's early grammatical development. As pointed out by Fisher (2002), young children's verb-specific patterns in production may mask their knowledge of broader structures because the children also have awareness that verbs differ in their subcategorization patterns. For example, whereas one can say both *It's spinning* and *It's falling*, only *spin* can be used in a transitive sentence such as *She's spinning the dial*. When children hear a new verb in one particular structure, they may refrain from applying the verb to other structures because, in fact, the verb might not be appropriate in these other structures. Thus, a child may hear *It's spinning* and not use *spin* in an utterance such as *She's spinning the dial* because some verbs (e.g., *fall*) cannot be applied in this way. Until the child gains greater exposure to the verb in different structures, generalization will be quite limited.

In contrast, in a comprehension task, a child who understands sentences such as *He's throwing the ball* might well select the correct referent event when asked "Show me *She's spinning the dial*" even if the child had only heard the new verb *spin* in sentences such as *It's spinning*. Hearing the test item *She's spinning the dial* might confirm for the child that *spin* can, in fact, be used in a transitive sentence. However, this may not have been a generalization the child was willing to make without additional evidence from the input. Indeed, evidence from preferential looking studies indicates that young children can use syntactic structure to interpret the meaning of sentences containing novel verbs (e.g., Hirsh-Pasek & Golinkoff, 1996; Naigles, 1990).

This tendency for production to adhere more closely to input history than comprehension has been replicated in a computational modeling study byChang et al. (2006). These investigators simulated learning tasks of both production and comprehension and used the same transitive sentences with novel verbs as input for both tasks. With repeated exposure, the model gradually developed an abstract transitive structure in production. However, the model developed accuracy in comprehending novel transitive sentences considerably earlier than the comparable attainment in production. Production responses were slower to deviate from the input. It is notable that this difference between production and comprehension emerged despite identical input.

The co-existence of verb-specific patterns and broader structures in grammatical development seems compatible with the implicit learning account provided byChang et al. (2006). Recall that this account assumes the long-term co-existence of both verb-specific combinations and more abstract structures. One advantage of this account is that it provides a reasonable explanation for how verb biases develop, such that certain verbs tend to occur in one structure whereas other verbs tend to occur in the alternative structure, even when the same verb is grammatical in either structure. For example, whereas the verb *sell* seems to occur more frequently in a prepositional dative structure, the verb *show* occurs more frequently in a double object dative structure (Gries, 2005). Similarly, the verb + particle

make up occurs almost exclusively with the particle adjacent to the verb (e.g., *They make up two-thirds of the starting lineup)*, whereas the verb + particle *ask in* occurs almost exclusively with the particle after the noun phrase (e.g., *We can ask all the visitors in now*) (Konopka & Bock, 2009). It is difficult to see how such biases could develop unless information about the particular verbs appearing in these alternative structures was being retained along with the structures themselves. Furthermore, because the verb-specific links are assumed to persist, this explanation meets the continuity assumption that should be met in any account of development. Note also that in construction grammar (Goldberg, 1995), a theoretical orientation compatible with input-based research (see Tomasello, 2003), it is assumed that constructions at different levels of abstraction co-exist in the adult grammar.

The co-existence of verb-specific patterns and more abstract structures assumed byChang et al. (2006) also helps to explain some of the experimental findings described earlier. For example, Akhtar (1999) found that three-year-olds who were induced to produce new verbs in a non-native manner (e.g., *Elmo the car gopped*) in keeping with the input they received, nevertheless alternated such productions with utterances (e.g., *Elmo gopped the car*) that conformed to the word order of their language. To apply the novel verb to the conventional word order without ever having heard the verb in that word order, these children must have possessed a broader structure that competed with the pattern associated with the novel verb's input.

The particular explanation provided byChang et al. (2006) for the lexical boost in priming can also contribute to our understanding of children's early verb-specific patterns. The lexical boost is thought to occur because the speaker has explicit memory of the wording of the immediately preceding prime, thanks to the recall cue provided by the (same) verb needed for the target sentence. Because material in explicit memory decays, the strength of this verb-specific effect diminishes, even though verb-specific information is incorporated into implicit learning along with structural information. In some of the studies of young children's verb-specific patterns, the children are presented with novel verbs in select structures and are then asked to produce the novel verbs in structures that either match or deviate from the structures in which the novel verbs originally appeared (e.g., Finneran & Leonard, in press; Theakston, Lieven, & Tomasello, 2003). In such studies, children show a strong tendency to use the novel verb only in the original, presented pattern. As discussed earlier, part of this narrow range of use might be attributable to the fact that, never having heard the novel verb in an alternate pattern, the children might simply be unsure if it can be applied in this way. However, in the procedure used in these studies, each novel verb is tested immediately after it is presented, and then the next novel verb is presented and tested. There is no opportunity to observe a diminution in the verb-specific effect. The children's responses might well reflect, in part, explicit memory, such that the just-presented verb to be used in the test item can cue the recall of the structure that had just been heard. Note that although the response might be influenced by explicit memory, the structure of the presented material can still contribute to implicit learning, just as primes involving the same verbs to be used in target sentences influence the learning of structure in addition to producing a lexical boost.

Accounting for Grammatical Errors in Development and in Priming

Another similarity between grammatical development and priming concerns the errors observed between the ages of two and four years of age. For example, some young English-speaking children produce utterances such as *Me do it*. Usually when accusative case pronouns are inappropriately used in subject position, they precede non-finite verbs, as in this example. Kirjavainen, Theakston, and Lieven (2009) found that young children's proportional use of such *me*-for-*I* errors was correlated with their caregivers' proportional use of *me* in preverbal contexts, as in *Let me do it*. Errors can also be induced by presenting

young children with novel verbs in contexts such as *Will the tiger heen?* (Finneran & Leonard, in press; Theakston et al., 2003). The same child who hears both *Will the tiger heen?* and *Look, the dog tams* will have a tendency to produce *heen* in a context obligating third person singular *–s* (e.g., *Every day the monkey heen*) but produce *tams* in a similar context (e.g., *Every day the bird tams*). Comparable findings appear to hold for missing auxiliaries. Input such as *We saw the frog meeping* and *Did you see him meeping?* are likely to induce young children to produce utterances such as *The duck meeping* and *Him meeping*, whereas input such as *The cat is swoping* is more likely to result in child utterances such as *The dog is swoping*.

The conclusion that utterances such as *The monkey heen* and *The duck meeping* are derived from input such as *Will the tiger heen?* and *We saw the frog meeping* must rely on an assumption that children are improperly extracting sequences such as *[the tiger heen]* and *[the frog meeping]* from the larger structures in which they appear. It must be assumed, then, that during some early period of grammatical development, children do not appreciate the structural ties within the larger structures that allow lexical verbs such as *heen* and *meep* to appear in non-finite form. In other respects, these errors have much in common with details seen in priming studies. First, recall that the units that seem to be primed are proposition-sized (Pickering & Ferreira, 2008). In fact, sequences such as *the tiger heen*, *the frog meeping*, and *me do it* meet this criterion. Recall as well that dependent clauses that appear in complex prime sentences have a priming effect, even when the structure of the dependent clause is used as a main clause in the target picture description (Branigan et al., 2006). Thus, based on the priming literature, it is known that a clause such as *the frog meepnig* is extractable from a larger structure such as *We saw the frog meeping*.

Each of these elements was confirmed in a priming study conducted with children by Leonard, Miller, Deevy, Rauf, Gerber, and Charest (2002). Both of the participant groups – a group of typically developing three-year-olds and a group of five-year-olds with SLI – were recruited because they were inconsistent in their use of auxiliary *is* (producing utterances with and without this form in contexts that obligated it). The children heard and repeated a prime sentence that accompanied a picture and then described a target picture that showed an ongoing action by a single agent. To ensure an obligatory context for auxiliary *is*, the target picture was accompanied by the experimenter's question "What's going on now?" In one of the prime conditions, the experimenter described the prime pictures with a complex sentence containing a non-finite progressive clause, as in *We see the mouse eating the cheese*. Leonard et al. found that, for both participant groups, the children's descriptions of the target pictures following these complex sentence primes were more likely to take a form such as *The horse kicking the cow* than their descriptions following no primes or primes that contained an auxiliary form. Target picture descriptions containing auxiliary *is*, such as *The horse is kicking the cow*, were most likely if an auxiliary had appeared in the prime sentence.

In summary, many of the findings of young children's co-existing verb-specific patterns and use of abstract structure seem highly consistent with known characteristics of structural priming. Even the errors characteristic of the early period of grammatical development seem to have a basis in the structural priming literature.

Grammatical Intervention as Priming

Given that grammatical intervention is intended to facilitate the grammatical skills of the children participating, and structural priming is known to influence grammatical use, the parallels between the two seem quite clear. However, it might also be argued that these

processes are not simply similar but one and the same. Here it is argued that much of grammatical intervention is priming.

Common Elements of Grammatical Intervention and Structural Priming

The relationship between grammatical intervention and priming is best explained by first considering the essential features of each. All grammatical intervention methods involve steps to ensure that the grammatical targets are presented with some degree of frequency in relatively unambiguous contexts. The activities themselves may be drill-like or conversational in nature, the grammatical target may or may not be made explicit during these activities, and corrective feedback may or may not be provided. The goal may be to help the child learn the target in production, or in comprehension with no requirement of production. At some point, the child's retention and generalization of the target is assessed, and intervention is not considered successful unless some degree of generalization is observed.

Importantly, in all intervention methods, clinicians are dependent upon the child implicitly learning to interpret and appropriately use the grammatical target. Intervention is intended to speed up the arrival date of this attainment by making the relevant information as clear and frequent as possible in the input. Nevertheless, it is up to the child to implicitly draw the necessary conclusions for intervention to succeed.

Structural priming, too, involves the frequent presentation of grammatical material in unambiguous contexts. The prototypical priming paradigm is somewhat drill-like, but the dialogue paradigm also used in priming is more conversational. The target (the structure of interest) can be made explicit, but usually is not. Given the nature of priming studies, corrective feedback is not involved, but encouragement certainly is, especially in priming studies with children. Many priming studies focus on production, but others examine comprehension effects (listening to primes) on production, and still others focus on whether comprehension is altered by hearing prime sentences.

As is true for grammatical intervention, generalization is central to structural priming. A participant's tendency to produce or comprehend a prime sentence is only the beginning of the process. Priming effects are not assumed unless the participant produces or comprehends a new sentence in a manner that reflects the influence of the prime.

There are two additional and important similarities between grammatical intervention and priming. First, grammatical intervention is designed to assist children's learning. Whether activities are highly structured or based on conversations during play, the goal is to alter children's knowledge of language, not to teach them to speak in a particular way during a circumscribed activity. Similarly, structural priming has come to be regarded by some investigators as a process that reflects implicit learning – the changes in linguistic behavior through priming appear to reflect changes in degree of knowledge about how intended meanings get mapped onto grammatical forms. Second, the targets selected for grammatical intervention activities are those that are difficult for the child but accessible given the child's current level of ability. In structural priming, the strongest priming effects seem to occur with structures that are relatively less well known by participants (Ferreira & Bock, 2006).

It is difficult to view grammatical intervention as fundamentally different from structural priming, apart from the fact that priming is an activity designed to alter the language behavior of individuals whereas intervention is an activity designed to alter the language behavior of individuals who appear to be at risk (Fey, 1986). Of course, this distinction is a crucial one, but it has more to do with intention than with the process itself. In fact, as discussed next, details from priming studies suggest several principles that can serve as

support for certain practices in grammatical intervention, and other details suggest adjustments that might be made during intervention activities to promote even greater gains in learning.

Some Intervention Principles Supported by Findings from Structural Priming

We begin with a caveat. Most priming studies focus on structures that the participants can already use. Therefore, the points set forth here are most applicable to cases in which the child is already producing the target structure to some minimal degree. However, there may be a difference between a child who shows no spontaneous use of the target structure and the child who has been found to lack all knowledge of the target structure. An inspection of the literature suggests that input can influence children's use of structures even when these structures have never been produced before. As a case in point, recall that Akhtar (1999) provided input that resulted in young English-speaking children producing sentences with non-English subject-object-verb or verb-subject-object word order. Thus, the ideas presented here may well be applicable to children who do not make use of the target structure, provided that they exhibit some minimal understanding of it.

Priming appears to be successful whether or not the prime is produced by the participant, and whether the target response is in the form of production or comprehension. These findings lend credence to a variety of grammatical intervention approaches, provided that these approaches offer the child with multiple examples of the target structure. This is certainly the case for traditional approaches such as modeling, that have been executed either with or without the child being asked to produce the modeled structure (e.g., Ellis Weismer & Murray-Branch, 1989). It also applies to approaches such as focused stimulation, in which concentrated exposures to target forms are provided, often in a story format with or without requesting production responses from the child (e.g., Fey, Cleave, Long, & Hughes, 1993; Leonard, Camarata, Brown, & Camarata, 2004).

These findings are also compatible with an approach such as conversational recasting (e.g., Camarata, Nelson, & Camarata, 1994; Leonard, Camarata, Pawłowska, Brown, & Camarata, 2006; Nelson, Camarata, Welsh, Butkovsky, & Camarata, 1996). In this type of approach – usually conducted in a play context – the clinician looks for opportunities to respond to a child utterance (the platform utterance) with a conversational reply (the recast) that contains the target form selected for treatment. Often, the platform utterance contains an error (e.g., a missing function word or inflection) that the recast serves to correct. However, given the results from priming studies, target forms presented in a conversational context need not correct the interlocutor's utterances. For this reason, the success of recasts might be attributed to the fact that they constitute a new form for the child; their corrective function may be less central to the gains seen with this approach. Indeed, Hassink and Leonard (in press) recently observed that recasts of both grammatical and ungrammatical child utterances can be successful even if the child's platform utterance did not contain an obligatory context for the targeted structure.

Intervention approaches differ in whether the clinician explicitly points out the target form to the child. Traditionally, this decision has been based on the child's age and developmental level. For older children, it has been assumed that intervention can be more efficient by simply explaining the form and function of the target to the children and providing a sufficient number of examples for practice. However, priming studies indicate that prime sentences can influence the structure of participants' own sentence use with no recall on their part of the material that served as primes. This is not to say that explicit reference to the target structure is unhelpful. However, it does not appear to be necessary for grammatical learning, a fact that may be helpful when children's metalinguistic abilities are rather limited.

Studies of priming as implicit learning make it clear that structural alterations in sentence use are not simply transitory adjustments made in the interest of speaking efficiency. Rather they reflect slight changes in the strength of mappings between meanings and structure that seemingly occur throughout the lifespan. For typically functioning adults, such changes do not have great importance outside of the laboratory, given that adults' command of most structures will be close to asymptote. However, for children, especially those with language impairments, the view of priming as implicit learning carries greater implications. Given current practice, once a child shows emerging use of a target structure, emphasis sometimes shifts to another structure because it is assumed that the child has acquired a basic level of competence with the first structure. That is, once it appears that the child "knows" enough about the structure to use it, any remaining gains might be regarded as changes in performance level, which might be assumed to warrant less clinical attention. However, we now know that gains do not simply reflect increases in level of performance but in degree of knowledge about the structure as well. For this reason, children's emerging use of the structure probably constitutes only a minimal level of knowledge; additional intervention is probably needed to ensure that the level of the children's knowledge is sufficient to enable them to use the new structure in typical speaking contexts.

The lexical boost seen in priming studies with adults represents an augmentation of the priming effect that already occurs through structural priming. For children, lexical effects may be different. Some priming studies with young children have shown that priming depends on whether the same verb is used in the prime and target. (Even in these cases, the child can produce target sentences that contain nouns that had not appeared in the prime.) Earlier, it was noted that children may, in fact, begin with verb-specific patterns that appear to gradually expand to broader, more abstract structures. However, it was also noted that these verb-specific patterns may simply reflect some uncertainty on the child's part about whether the particular newly learned verbs can take part in alternative structures that the child already knows. In either case, these verb-specific patterns do not disappear. Although they become subsumed under broader structures, they retain a life of their own and may contribute to the lexical boost that co-occurs with structural priming even in adults. Because verb-specific patterns are not developmental dead-ends, they can be treated as good starting points as clinicians present multiple examples of the target structure during intervention.

Priming in both adults and children suggests that the units that show effects are approximately the size of propositions. In the case of English, propositions will include a subject, verb, and any arguments that are obligated by the verb. For the effects that immediately or gradually lead to structural changes in children's grammars, proposition-sized units seem most appropriate.

The structures serving as targets should not be limited to those expressing a single thematic relation. For example, even though dative and locative relations are not the same, their common expression by means of a structure with a prepositional phrase seems sufficient for one to influence the other. These findings suggest that a phrase structure level of presentation seems most appropriate.

Input effects are especially obvious when a clinician's stimulus utterance is immediately followed by the child's response. However, based on data from adults, it may be the case that intervening utterances by the clinician can occur before the child responds, provided that the input structure has been presented frequently and in clear contexts.

Findings from priming studies also point to areas in which some caution should be exercised during intervention activities. For example, many treatment approaches make use of a group format, in which the clinician provides language input to several children simultaneously. It

may be the case that success in this format will not be especially efficacious unless the clinician ensures that a sufficient number of utterances are directed to each individual child, along with any utterances that are intended for the group as a whole. Structural effects on utterances appear to be stronger when the participant (the child, in this case) is the intended recipient of the adult's message.

Finally, although extracting clauses from larger structures can have adaptive uses, there is a risk when larger structures are used with young children and those with language impairments. When the extracted clause would be an ungrammatical proposition (e.g., *Him running* from *We saw him running*, or *She go* from *Will she go?*), it would be best to avoid presenting targets within larger structures. Alternatively, clinicians could ensure that the child understands the larger structure before employing input of this type. Fey and Loeb (2002) discussed a potential case of confusion that is directly related to this issue. To promote auxiliary use, these investigators provided the children with auxiliary-fronted questions such as *Is Daddy driving the truck?* Gains in auxiliary use following this procedure proved to be quite limited and even smaller than gains seen in children who simply participated in play activities. Fey and Loeb proposed that the children did not understand the syntactic structure of the auxiliary-fronted questions, and as a result inappropriately extracted for their own use the utterance-final sequences such as *Daddy driving the truck*.

Summary

Structural priming is not restricted to the laboratory; the effects of priming are seen in everyday language use. As in ordinary language use, priming can occur in a conversational context, and speakers do not pay close attention to the grammatical structures they employ when conveying their intended meaning, even when those structures were influenced by a prime. Priming also reflects a learning process. Alterations in grammatical form reveal not only speaking choices made in the moment but also gradations in the speaker's knowledge of how meanings and structure map onto each other. These characteristics of priming suggest that details from priming studies can inform both the study of children's grammatical development and the intervention activities we adopt for children with grammatical impairments.

Regarding grammatical development, the co-occurrence of verb-specific effects and structural priming in adults lends much credibility to the view that children can likewise produce utterances that reflect both structural knowledge and verb-specific influences. The joint effects of these different levels of grammar seem to persist throughout our speaking lives.

Regarding implications for grammatical intervention, the findings from priming studies reinforce the tenets of particular treatment approaches that emphasize clinicians' use of frequent targeted input. In addition, priming details suggest ways to fine-tune intervention activities such as providing frequent child-specific input during group activities, and selecting as targets proposition-sized units at a phrase structure level, among others. Of course, before these details can be confidently incorporated into grammatical intervention activities, their potential value should be confirmed through empirical study. It seems that the clear parallels between structural priming and change through intervention can provide a strong rationale for pursuing this type of research.

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